Public Interest Energy Research (PIER) Program

FINAL PROJECT REPORT

RETAIL REVISIONING

Task 2 of the PIER Daylighting Plus Research Program

Prepared for: California Energy Commission

Prepared by: Heschong Mahone Group, Inc.

HESCHONG MAHONE GROUP

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Retail Revisioning is the final report for the Retail Revisioning project, Contract Number 500-06-039, conducted by Heschong Mahone Group, Inc. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

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For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The use of daylighting in retail stores has had a positive effect on energy consumption in California. This had been accomplished largely through the development and implementation of codes and standards related to ”big-box” retail buildings, where uniform illumination is needed. The use of natural lighting remains largely absent from specialty and high-end, or “fancy box,” retail, where merchandising and aesthetic concerns are higher priorities than energy conservation. This project developed daylighting strategies that provide the inherent energy saving benefits while balancing the merchandising and aesthetic priorities of “fancy box” retail design. The project pioneered solutions to address these unique challenges by combining a research organization (Heschong Mahone Group), a leading retailer (Federated Department Stores) and a respected design organization (International Association of Lighting Designers). Future energy efficiency programs and design efforts can take advantage of the retail daylighting strategies developed through this project to expand the reach of daylighting in retail stores. These strategies can benefit California ratepayers by reducing energy use associated with lighting on average by about 30%.

Keywords: Retail, retail revisioning, retail daylighting, daylight, daylighting, California, skylight, window, lighting, California Energy Commission, PIER, Heschong, Pande, Heschong Mahone Group, Inc., PIER, Daylighting Plus

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Introduction

The Daylighting Plus PIER research program aims to promote better understanding of daylighting potentials, strategies, and metrics. The intent is to increase energy savings by using more daylighting and less electrical lighting in California's commercial buildings. This program encompasses a coordinated suite of research projects and related market connections activities.

Led by the Heschong Mahone Group, Inc., the Daylighting Plus program consists of four program elements addressing the appropriate use of daylighting. The Retail Revisioning Project element of the PIER Daylighting Plus program focused on developing and demonstrating daylighting design approaches for high-end, or "fancy box," retail stores that can both enhance visual marketing and provide significant energy savings. The project team worked with Federated Department Stores and other retail designers and owners to develop innovative approaches to lighting that combined both marketing and energy conservation objectives.

Purpose

The use of daylight has become widespread in so-called "big-box" retail stores in California, where abundant natural light provides a valuable resource for illuminating large warehouse-like spaces. However, natural light remains largely absent from specialty and high-end, or "fancy box," retail, where merchandising and aesthetic concerns are higher priorities. The intent of this project was to develop daylighting strategies that provide the inherent energy saving benefits while also balancing the merchandising and aesthetic priorities of "fancy box" retail store lighting design.

Objectives

This project encouraged, demonstrated, and disseminated new approaches to retail lighting design that could result in greater energy savings and peak demand reduction, while satisfying the need of the higher-end retail businesses for effective visual marketing and the creation of a highly attractive shopping environment. The intent was to transfer mature lighting concepts from museum and religious lighting designs, where low ambient lighting is necessary, to retail businesses, where the current paradigm centers on the use of high-energy, theatrical style lighting designs.

The objective of this project was to engage a major operator of high-end retail buildings (Federated Department Stores), a utility partner (Sacramento Municipal Utilities District [SMUD]), and the International Association of Lighting Designers (IALD) to develop a new paradigm for lighting quality and energy-efficient lighting in retail facilities. The project sought to achieve its goals through a combination of demonstrations, design assistance, and monitoring of new retail buildings and the development of a new retail lighting method that is both energy-efficient and visually appealing and stimulating.

Project Redirection

The original project centered on building a new prototype store in conjunction with the retail partner, using the techniques and strategies that were developed in the initial project tasks. Due

to unforeseen changes in the economy that severely affected the retail sector starting in 2008, tasks for this project were reorganized in response to new economic conditions. Contraction in the retail sector resulting from the economic downturn resulted in a complete stop to construction of new stores in California. The project tasks were reorganized around the following tasks:

- Create a business case for daylighting in retail stores based on evaluating the value of daylighting as a high-quality illumination source rather than focusing exclusively on the energy savings aspects of daylighting.
- Evaluate daylighting strategies currently incorporated in retail stores, museums, and other notable daylit buildings to further develop daylighting strategies for retail buildings.
- Design and implement a daylighting intervention study at an existing store location.
- Develop prototype daylighting strategies for new construction.
- Conduct a workshop with IALD members and architects on the longer-term direction and strategies for daylighting in retail stores.

Conclusions

The project team and retail partner conducted design survey visits to various daylit buildings throughout California. The project team identified several strategies to integrate or improve daylighting in retail stores. The strategies described below will help improve both the impression and effectiveness of daylighting in retail buildings:

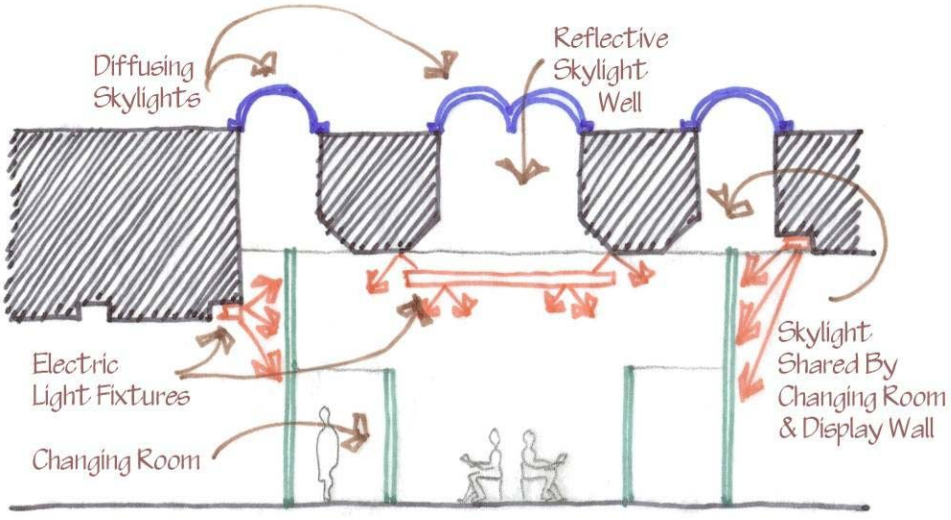
- Using cooler colors in skylight lightwells visibly differentiates the lightwells from the rest of the store. This provides visual variety and refreshment for customers who stay in the store for a longer time. This also draws customers' attention to the presence of daylight.
- Drywall bulkheads are usually 2' from the window, which means that a lot of daylight that could be admitted into the store is absorbed by the bulkhead, or reflected back out of the building. The areas of window above the bulkhead are adding to the energy load of the store but not contributing any daylighting. The bulkheads could be drawn back several more feet to allow more daylight into the space.
- Consistent use of light-colored tiles in daylit areas is preferred since they reflect more daylight than dark-colored tiles; they not only appear brighter but make the ceiling and merchandise appear brighter.
- Providing a low level of ambient daylighting throughout the store provides color contrast using accent lighting but may overwhelm accent lighting at times. Variation in the appearance of the store through the day provides a more natural and stimulating environment for the staff. Customers are unlikely to perceive the store as daylit due to high uniformity.
- Daylight Modulation − Deliberately creating controlled differences in brightness between adjacent areas of the store by using overhead skylights can serve as visual

- Orienting Displays Perpendicular to Windows and Doors - In many cases, display walls have been built immediately in front of windows, blocking the light and creating high contrasts between the remaining visible parts of the window and the display itself. Displays could be re-oriented or otherwise changed to make effective use of the daylight to display merchandise.

Based on these survey findings (strategies), the project team and partners conducted a design workshop to identify opportunities to incorporate daylighting into retail prototype designs. The team identified the following opportunities:

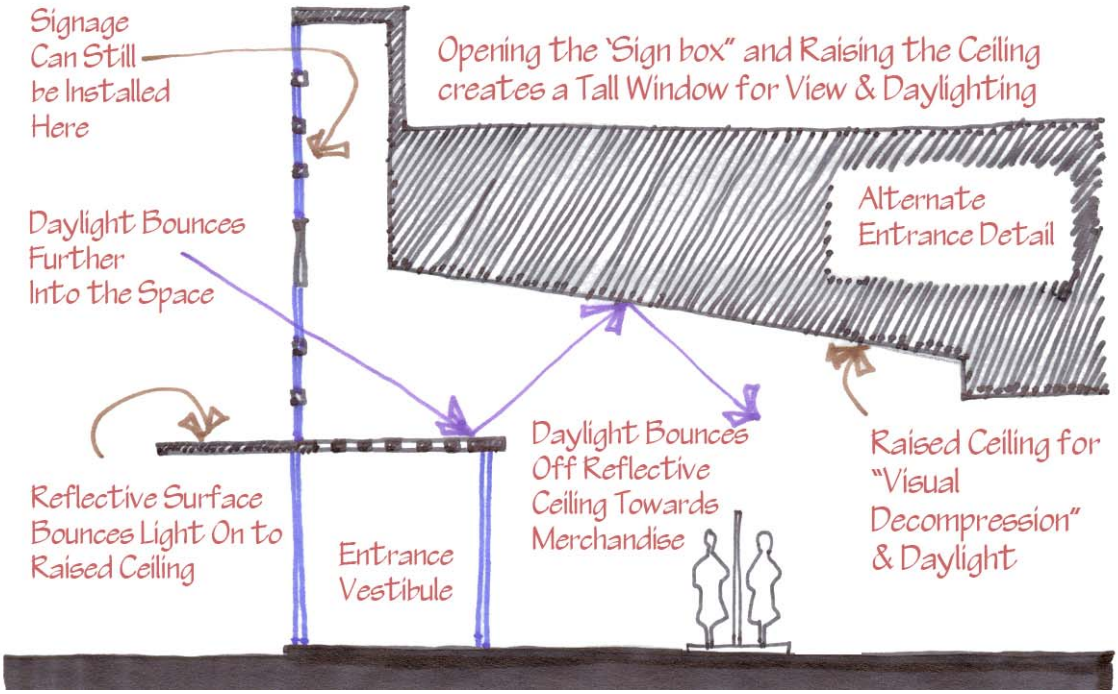
- *Daylight for Vivid and Natural Colors:* Daylight is the best possible source of lighting for vivid and accurate color rendition of objects because it is a full spectrum light source and the one most commonly used in our daily life to judge the appearance of objects. Furthermore, the balance and presence of all wavelengths in this source mean that subtle colors, especially skin tones and the colors of other natural objects, are best compared under daylight.
    - To take advantage of this potential, one of the applications for daylighting is to incorporate skylights into dressing and changing rooms. This provides customers with the opportunity to see natural skin tones, and fabric colors as they will be experienced outside of the store. An example is shown in Figure 1.

Figure 1: Skylighting in Changing Rooms



- *Daylight for Attraction:* Humans are naturally "photo-tropic." Their attention is naturally drawn to brighter scenes. Daylight can provide visual nourishment and focus for consumers in the store. Highlighting areas of interest or attraction is a natural use for daylight, which will usually be brighter than any electric source. Pools of daylight can be used to draw a customer deeper into a store, or into a back wall.
- *Daylight for "Wayfinding":* Daylight can be an effective strategy for highlighting sections of the store to provide "wayfinding" for customers in the store. An example is to provide daylight near entrances to reinforce customers' sense of orientation, and provide emotional emphasis to the indoor-outdoor transition. Alternatively, daylight might be effectively used to highlight corners using windows to get customers' attention to corners of the store otherwise not easily visible from the center of the store.
- *Daylight for Accentuating Pathways:* Daylighting is very effective at creating linear pathways, marking the primary way to move through a space. For example, this can be done with a linear "rhythm" of skylights to accentuate walkways near high-value merchandise areas.
- *Daylight for "Visual Decompression":* A good deal of discussion with designers and the research team's retail partner centered on the use of daylight for "visual relief" or "decompression" to customers fatigued from walking around in electrically lit indoor environments. A pool of daylight on a sitting bench, and/or an attractive view to the outdoors, can provide momentary relaxation and rejuvenation from intensive shopping.
- *Daylight for Drama and Emotional Resonance:* Daylight is inherently variable, varying in intensity and pattern of distribution throughout the day. This variation can work to create more drama and emotional resonance than any stage design. Bright spots of sunlight highlighting merchandize can be magical, partly because of intensity, and partly due to the fleeting nature of the moment. Pools of daylight in displays can create a more "home-like" ambience and/or seasonally appropriate lighting conditions.
- *Enhanced Use of Daylight at Entrances:* Discussions with the team's retail partner and designers resulted in several strategies to convert the existing glazing in retail stores – primarily the glazing near entrances − into usable daylighting apertures. A number of retail stores include significant amount of glazing that is essentially a false façade to highlight signs or merchandise or in some cases as a purely aesthetic statement. These don't add any daylight to the interior of the store since there is usually a drywall behind this glazing, and thus the glazing is neither visible nor useful from inside the store. A number of options were discussed to convert these "sign boxes" into useful daylighting apertures. One such alternative is presented in Figure 2.

Figure 2: Detail for Entrance Glazing for Daylighting



- *Improved Window Details:* Similar to the entrances, there is often a significant amount of glazing on the exterior walls of retail stores for product display, but often only used for signs and/or visual branding.
    - The team identified solutions to raise the ceiling near windows to bounce daylight deeper into the space. Use of semitranslucent panels, such as digital prints, instead of opaque platforms for merchandise displays creates a backdrop for the displays, while still letting some daylight and views into the interior.
    - Other alternatives include adding skylights to balance the daylight from the windows, setting the displays at 90 degrees to the windows (instead of back-to-back), and/or adding perpendicular wall surfaces adjacent to the windows to direct daylight into the space.

The project team then conducted a small-scale daylighting intervention study at an existing retail store in California's Central Valley. This store originally had skylights that were subsequently covered during building retrofits due to excessive heat gains from the large skylights. The daylighting design succeeded in providing daylight in the study area while avoiding overillumination under the skylight or causing excessive contrast ratios with other parts of the store. The relatively small budget spent by the retail partner on the daylight retrofit strategy and the resulting daylighting conditions indicates that it is feasible to "fix" issues with existing skylights in stores that are overglazed and, therefore, often covered up to save energy and maintain visual conditions.

While there are still opportunities for continued improvement, the intervention study has resulted in quantifiable improvements in the visual conditions of the study area. The intervention study achieved expected results, creating a more attractive retail environment for both sales associates and customers. The intervention strategy chosen for re-opening the skylight has resulted in good lighting quality and reduced heat gains that, when combined with proper lighting controls, will result in energy savings. The results of the intervention study suggest that similar actions could be taken in other similar retail settings. Since there are a number of older retail stores in California with inefficient daylighting, there is significant potential for daylighting retrofits in the state. Daylighting strategies can benefit California ratepayers by reducing energy use associated with lighting on average by about 30%.

Recommendations for Future Activities

Continued Education on Daylighting Design

Lack of knowledge of how to design buildings to include daylighting and how to design electric lighting that compliments daylighting are significant obstacles to daylighting retail buildings.

Currently, there is very limited information regarding daylighting available to lighting designers as part of their formal training and work experience. Conversations with IALD and other lighting professionals identified the need for formal education on daylighting strategies. Daylighting, like other architectural solutions, does not lend itself to a set solution that can be copied as-is across buildings and locations. Daylighting strategies need to be grounded in the needs of the individual building, and the associated location and climate characteristics. Education on climate, especially the movement of the sun and its effect on solar gains and illumination in space, is critical to achieving good daylighting design.

Future Research

Further studies on daylighting control options are needed for retrofitting daylighting into existing retail stores. Wireless controls are promising, but the technology is too new to be adopted directly by retailers. Demonstrations of the feasibility and cost-effectiveness of wireless controls are needed to convince retailers and lighting designers that this is a desirable and a viable alternative to traditional lighting designs.

The daylight intervention study conducted by HMG for this project focused on skylighting solutions. Similar intervention study is needed for sidelighting applications of daylighting to show retailers that introducing daylighting through windows is feasible and beneficial.

The current retail-revisioning project achieved initial success in showing correlation between presence of daylighting in the high-end retail environment and positive responses from customers and sales associates. However, the study could not fulfill its original goals of monitoring daylighting and energy usage in new construction due to decreases in commercial retail construction that eliminated most, if not all, new construction in California.

Through partnership with its retail partner, HMG has been successful in developing daylighting strategies that have been adapted into prototype store designs, and into a few stores which have been built outside California. Stores built on this prototype design will eventually

be built in California once construction activity resumes in the State. At such a time, a follow-up study to evaluate effectiveness of the daylighting strategies would provide critical feedback to the retail partner as well as other retailers who can benefit from daylighting strategies.

CHAPTER 1:
Introduction

1.1 PIER Daylighting Plus Program

The Daylighting Plus PIER research program aims to promote better understanding of daylighting potential, strategies and metrics with the aim to increase energy savings from daylighting and associated electric lighting in commercial buildings in California. This will be achieved through a coordinated suite of research projects and related market connections activities.

Led by the Heschong Mahone Group (HMG), the Daylighting Plus program consists for four program elements addressing the appropriate use of daylight:

The Daylighting Metrics Project, addressed by this report, worked with the International Engineering Society of North America (IESNA) and an international team to develop and test new daylight performance metrics and criteria, based on annual simulations. The goal is for these metrics to provide better criteria for appropriate daylighting design, tailored to climate, building operating characteristics, and advanced design options, which can then be adopted into codes and voluntary standards.

The Retail Revisioning Project worked with Federated Department Stores and other retail designers and owners to develop and demonstrate daylighting design approaches for "fancy box" retail stores that can both enhance visual marketing and provide significant energy savings.

The Office Daylighting Potential Project set out to quantify the market potential for retrofitting existing office space in California to maximize daylighting energy saving potential, and develop assessment tools for new daylighting retrofit programs.

In addition, a program-wide market connections effort assisted the project-level objectives by hosting outreach events and forums for discussion of the range of issues addressed by this program, and of concern to the PIER Program. These activities facilitated the exchange of knowledge generated by this program to the appropriate audiences, and generated further discussions and market connections among the participants.

1.2 Retail Revisioning Project Background

The use of daylight has become widespread in so-called "big-box" retail in California, where abundant natural light provides a valuable resource for illuminating large warehouse-like spaces. However, natural light remains largely absent from specialty and high-end, or "fancy box," retail, where merchandising and aesthetic concerns are higher priorities. The intent of this project was to develop daylighting strategies that provide the inherent energy saving benefits

while also balancing the merchandising and aesthetic priorities of "fancy box" retail design. By combining a research organization (HMG), a leading retailer (Federated Department Stores) and International Association of Lighting Design (IALD) the team set out to develop solutions that address these unique challenges.

1.3 Project Goals

The goal of this project was to encourage, demonstrate and disseminate new approaches to retail lighting design. These approaches seek energy savings and peak demand reduction, while more than satisfying the need of the retail corporation for effective visual marketing and the creation of a highly attractive shopping environment. The intent was to transfer mature lighting concepts such as low ambient lighting as the ideal approach, rather than the current paradigm which is the use of high-energy theatrical style lighting.

1.4 Project Objective

The objective of this project was to engage a major operator of high-end retail buildings (Federated Department Stores), a utility partner, Sacramento Municipal Utilities District (SMUD) and IALD in the development of a new paradigm in lighting quality and energy-efficient lighting in retail facilities. The project sought to achieve its goals through a combination of demonstrations, design assistance, and the development of a new retail lighting method that is energy- efficient and visually-appealing.

CHAPTER 2:
Project Research Plan

2.1 Original Task Order

The development of new approaches and strategies for daylighting in high-end retail was broken down into several tasks, as outlined below:

- Task 2.1 – Research Plan: Develop a research plan for the project.
- Task 2.2 – Exploratory Project: Test the sales impact of overhead daylighting in an existing California store site that was previously daylit. This was intended as an experiment to explore the role of daylighting in the target retail environments.
- Task 2.3 – Corporate Business Case: Communicate to the upper management of the retail partner the value of this new approach to lighting on a company-wide basis. Efforts for this task will provide valuable insights that will help the project and program level market connection activities.
- Task 2.4 – Experimental Store Design: Explore several design options in collaboration with the Project's utility and retail partners on the development of an experimental store (100,000 sf single story lifestyle center in the utility service territory planned for construction in 2008).
- Task 2.5 – QC Construction of Experimental Store: Provide quality control and design troubleshooting during the construction of the experimental store. Report on the implementation of measures discussed in the task 4 report and the impacts of any changes in measures on energy and cost/benefit ratio. Report on construction challenges and resolutions to these challenges so that others who wish to follow suit may learn from the experience of the project.
- Task 2.6 – Performance Analysis of Experimental Store: Evaluate the performance of the design of the experimental store, analyze the monitoring data, and produce energy profiles for the overall store and its discrete measures.
- Task 2.7 – Retail Innovation Process: Report on the overall design and construction innovation process, both in terms of design challenges in integrating new technologies into the physical store, and also in terms of social and organizational challenges in addressing corporate concerns about the new design.
- Task 2.8 – New Store Prototypes: work with the utility and retailer partners to use lessons from Task 2.2 through 2.6 to develop a new prototype for retail stores in California that can lead to adoption of new retail design strategies by Emerging Technology programs.
- Task 2.9 – Market Connections – IALD Workshops and Publications: Reach out to the lighting designer community through interactions with the IALD both to inform and learn from the process used in this project.

- Task 2.10 – Code Implications: Analyze and report on the implications of the project's findings for California's Title 24 energy standards.

2.2 Contingency Plan and Reorganization of Tasks

Due to unforeseen changes in the economy that severely affected the retail sector starting in 2008, tasks for this project were reorganized in response to new conditions. The original organization of this project centered on building a new prototype store in conjunction with the retail partner, using techniques and strategies developed in the initial tasks of the project. However, due to the contraction in the retail sector resulting from the economic downturn, the retail partner decided against constructing new stores in California in the near future. Instead, many of the project tasks were reorganized around the implementation and outcomes of a small-scale intervention study at a single store location, while whole-store prototype strategies were developed simultaneously. This reorganization kept the same form as the original scope of work, with modified tasks. As such, some of the tasks took place in a different sequence, or simultaneously, rather than sequentially. For example, task 2.8 was completed before tasks 2.4 through 2.7, to fit the schedule and needs of the retail partner.

The reorganized tasks are outlined below:

- Task 2.2 – Exploratory Project: The exploratory project involved a tour and survey of existing retail and museum buildings in California that are currently utilizing daylight. Recommendations from this task addressed how existing stores can better utilize daylight opportunities and how new construction can incorporate daylighting in store designs.
- Task 2.3 – Corporate Business Case: This task included a design charette, working with the retail partner's staff on strategies to integrate daylighting in future stores, and to communicate the value of daylighting in retail design. The advice and recommendations included findings from the analysis of prototype studies carried out in task 2.8. Task 2.3 also includes a summary report of the outcomes of a design charette with the retail partner on daylighting options in retail stores.
- Task 2.4 – Experimental Store Design: This task included the strategy and design of a daylighting Intervention Study at an existing store location.
- Task 2.5 – QC Construction of Experimental Store: This task involved overseeing the implementation of the daylighting Intervention Study.
- Task 2.6 – Performance Analysis of Experimental Store: Task 2.6 included analysis and evaluation of on-site surveys and sales performance data resulting from the Intervention Study.
- Task 2.7 – Retail Innovation Process: Task 2.7 provides a retrospective analysis of daylighting integration strategies for high-end retail buildings. This retrospective includes results and findings from Tasks 2.3 through 2.6 at a high level addressing the challenges and potential solutions to bringing daylighting into retail buildings.

- Task 2.8 – New Store Prototypes: This task involved daylight modeling and economic analysis of several proposed daylighting strategies for retail store prototypes. Findings from this task were used to inform strategies in the design charette under Task 2.3 as well as the design and implementation of the Invention Study in Tasks 2.4 through 2.6.
- Task 2.9 – Market Connections - IALD Workshops and Publications: This task did not change from the original scope.
- Task 2.10 – Code Implications: Analyze and report on the implications of the project's findings for California's Title 24 energy standards.

2.3 Project Timeline

Project tasks were carried out according to the following schedule:

- Task 2.2 – Survey of existing daylighting conditions - February, 2008
- Task 2.3 – Design charette - April, 2008
- Task 2.4 – Strategy and design for the Intervention Study - August, 2009
- Task 2.5 – Oversight of the implementation of the Intervention Study - September, 2009
- Task 2.6 – Analysis of the Intervention Study – October 2009 through October 2010
- Task 2.7 – Review and analysis of findings from the Intervention Study – October – December 2010
- Task 2.8 – Modeling and analysis of daylighting strategies began in July, 2007, to inform the charette and intervention study design process in Task 2.3
- Task 2.9 – Outreach events with the lighting design community - ongoing through the end of the project
- Task 2.10 – Analysis of project implications for code process January 2011

CHAPTER 3:
Retail Store Design Assistance

Prototype designs are a key component of the retail design process. Regional and national retail store chains rely on prototypes to create a consistent look and feel across all of their stores. Almost all major design decisions for major department store retailers, like the retail partner on this project, are made at the prototype level. Since prototype designs are adapted to a wide variety of sites, it is important that design decisions are appropriate for a range of climate conditions and building orientations.

The nature of the prototype process has both advantages and disadvantages for daylighting. The necessity for prototype designs to fit into a variety of conditions prevents the kind of orientation-and geography-specific solutions that daylight is inherently suited to. However, the need for more universal daylighting solutions in prototype designs may make daylighting possible even when orientation or geographical conditions are not ideal for more site-specific solutions.

3.1 Generic Retail Store Designs

The retail partner was developing two store prototypes, and these were used to develop and discuss daylighting opportunities. The prototype designs include a single-story store geared toward the growing trend in "lifestyle center" malls, as well as a more traditional two-story store design. More detailed information on the store designs and specific daylighting strategies is included below in Appendix A:.

3.2 Daylighting Strategies

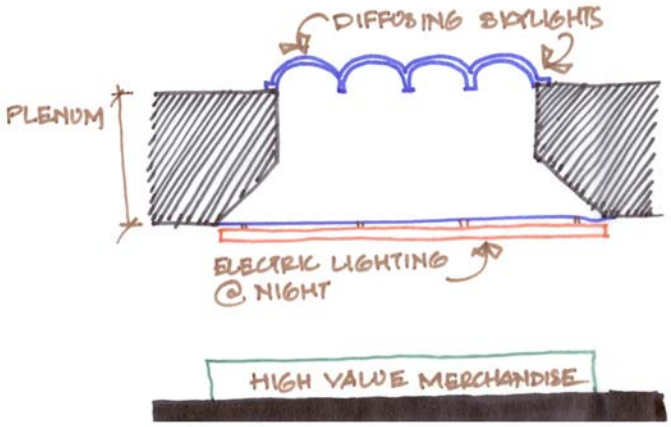
Based on the prototype stores designs, HMG developed recommendations for daylighting strategies that the retail partner could integrate into their new stores. Due to the retail partner shifting more attention to the single-story "lifestyle center" model, the proposed daylighting strategies focused on this prototype. The single-story plan also allows for access to daylight throughout the store, since the entire store area is directly beneath the roof.

HMG developed daylighting strategies that built on the existing architectural features of the prototype. Daylighting strategies focused on circulation paths, architectural elements, and feature areas in the store based on communication with the retail partner.

Traditional two- and three-story department store designs often have daylit atrium areas for circulation between floors. While the single-story prototype store has no need for a central atrium for vertical circulation, HMG recommended providing a large central skylight at the intersection of the two main axes, above the high-value merchandise area, as a reminder of this traditional feature, as well as to provide a wayfinding reference for shoppers. Figure 3, below,

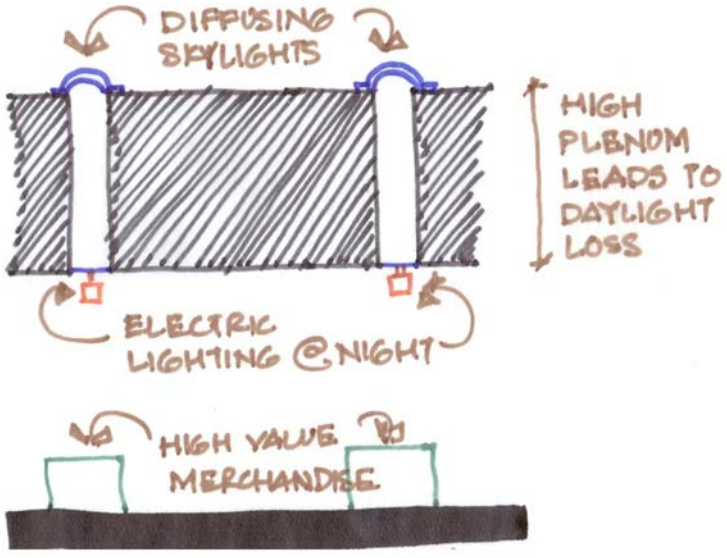
shows a section through this proposed skylight, illustrating its location above the central high-value merchandise area.

Figure 3: Section Through Proposed Central Skylight



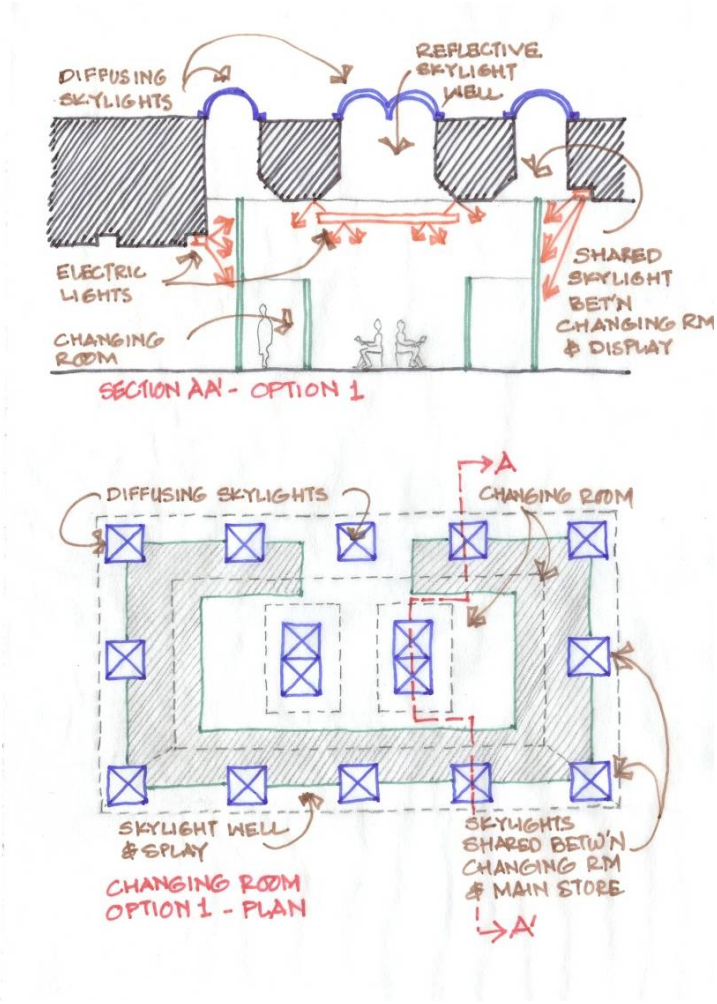
The prototype design also featured a series of linear electric lighting elements along the long axis of the store, over the high-value merchandise area. The electric lighting fixtures, oriented perpendicular to the long axis, create a visual rhythm through the store. HMG used the pattern created by these lighting elements to introduce an opportunity for daylighting along the main axes. HMG proposed using narrow skylights, aligned with the electric lighting elements, as shown in Figure 4. These skylights provide daylight to highlight the high-value merchandise areas, but the deep and narrow light wells help to diffuse the light and temper the intensity of the daylight to prevent glare. This strategy also provides an opportunity for electricity savings, reducing or eliminating the need for electric lighting during the day.

Figure 4: Section Through Proposed Skylights Over High-Value Merchandise



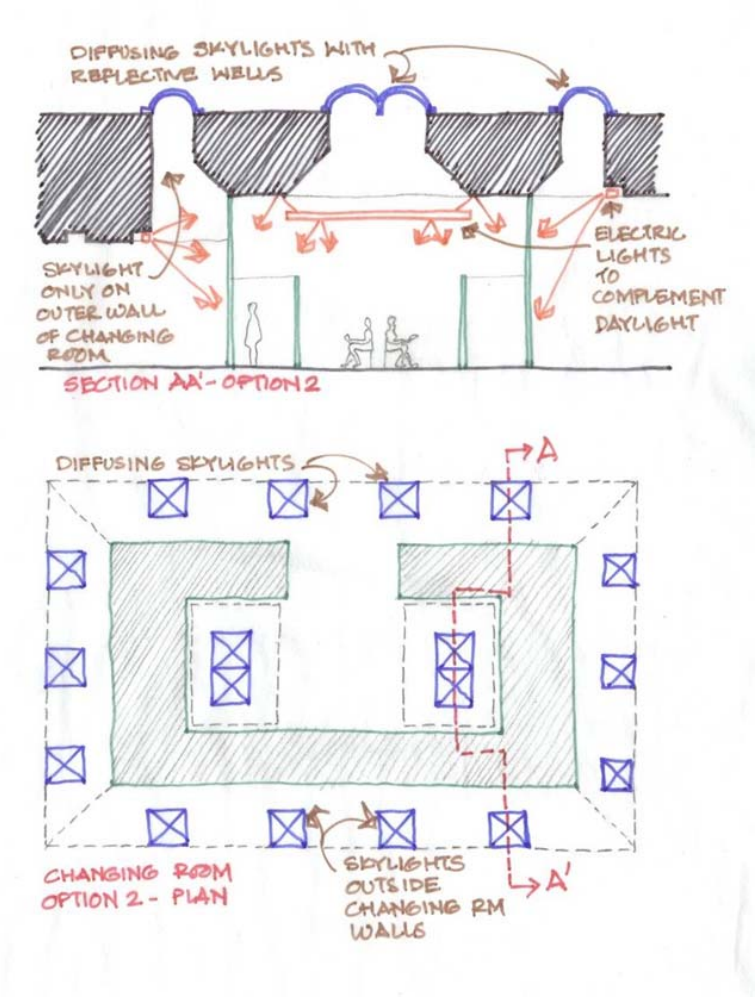
One of the key strategies focused on providing daylight within and around the four fitting room "anchors." This option involved introducing daylighting in the fitting rooms using an array of standard sized skylights. Providing daylighting in the fitting rooms was one of the key sales advantages of introducing daylighting in the retail environment. Natural light in the fitting rooms would provide the best color rendition for the merchandise, as well as presenting the customer in the best light. HMG believes that providing this high-quality daylight in the fitting rooms could lead to increased sales. This strategy also involved placing skylights along the perimeter of the changing room cores to wash the walls with daylight, creating a visual attraction to aid in orientation and wayfinding for shoppers, as well as enhancing merchandise displayed on these walls. Two options, shown in plan and section below in Figure 5 and Figure 6, were proposed for the skylights in the fitting rooms.

Figure 5: Section Through Fitting Room – Option 1



The first option, in Figure 5, shows the perimeter skylights illuminating the interior of the fitting rooms, as well as the exterior walls. By placing the skylights straddling the outer wall, the fitting rooms receive even and diffuse daylight from multiple directions. The section in Figure 5 also illustrates how electric lighting (shown in red) will supplement daylighting in the fitting rooms.

Figure 6: Section Through Fitting Room – Option 2



The second option, Figure 6, has the perimeter skylights entirely outside of the fitting rooms, only illuminating the exterior walls. This option will focus more daylighting on the perimeter

walls of the fitting rooms, highlighting merchandise displays. Once again, the section drawing illustrates how electric lighting (shown in red) will supplement the daylight.

The option 1 proposal (Figure 5) is considered to be preferable because it provides natural lighting in the fitting rooms more uniformly and from multiple directions, avoiding shadows that may be unflattering for customers and merchandise.

Sections in Figure 7 and Figure 8, below, illustrate overall daylighting strategies for the single-level prototype. Figure 7 shows the section through the long axis of the building, illustrating the narrow skylights over the high-value merchandise area, while Figure 8 shows the fitting room and central atrium proposals.

Figure 7: Section Through Long Axis

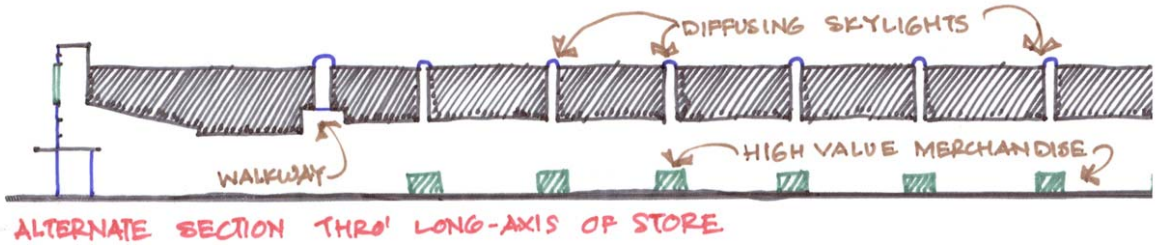
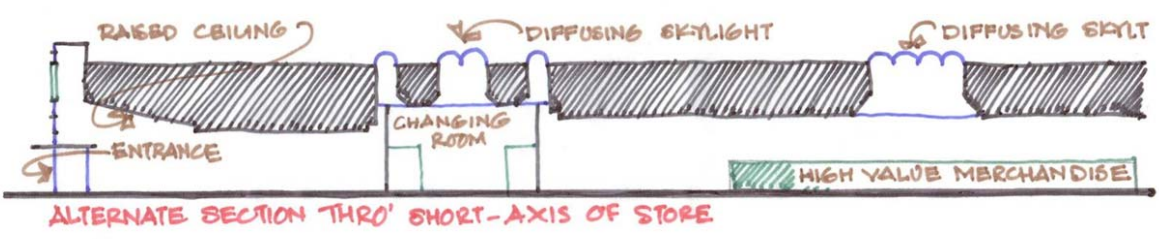


Figure 8: Section Through Short Axis



HMG also proposed the use of skylights in stock rooms and support spaces, where natural light could replace electric lighting during daylight hours. In addition to the potential energy savings of using skylights in the stock rooms, daylight could provide higher illumination levels in the sometimes dark spaces, and make it easier for sales associates to find what they are looking for.

3.3 Simulation Analysis of Daylighting Strategies

The majority of the daylighting strategies proposed by HMG were intended to improve the customer experience in the store and the visual quality of the merchandise, and thereby to increase sales. For these strategies, energy savings was not the primary goal. However, in the stock rooms and support spaces, where customer experience and sales are not a factor, energy savings and economic benefit was a more significant consideration.

HMG used a daylight simulation program called SkyCalc to estimate cost and energy savings from the use of skylights in the stock rooms. Results from SkyCalc were used to refine daylighting design strategies, as well as to estimate the payback time for the added cost of installing the skylights. HMG performed simulation and analysis for three locations throughout the United States where the retail partner was planning on developing new stores: Sacramento, California; Phoenix, Arizona; and Dallas Texas. The simulations assumed a total of 21 standard 4′ x 8′ skylights to serve the 16,960 square feet of stock room space in the single-story prototype model (achieving a skylight to floor area ratio of 4.00 percent). The cost of the added skylights was estimated to be $21,700 per store, including the cost of lighting controls and wiring to enable daylight-responsive electric lighting. An incentive program offered by the Sacramento Municipal Utilities District was also factored into the analysis for Sacramento location, but not for the other locations. Local weather files and utility rates were also used.

Initial simulations assumed only daylighting controls in use in the stock rooms. However, the retail partner was already using occupancy sensors in their stock rooms as part of their standard practice, so an additional round of simulations were performed that accounted for the use of daylighting and occupancy controls. Detailed results of the simulations are shown below in Figure 9.

Figure 9: Summary of Energy and Economic Analysis for Stock Room Skylights

	Sacramento, CA	Phoenix, AZ	Dallas, TX
CASE 1: Assuming NO OCC. SENSOR			
Annual Energy Savings (kWh)	31,422	30,462	29,663
Annual Operating Cost Savings ($)	$2,813	$2,627	$3,392
Annual Rate of Return (%)	8.91%	8.18%	9.51%
Simple Payback (years)	7 years	8 years	6 years
CASE 2: Assuming OCC. SENSOR			
Annual Energy Savings (kWh)	11,922	9,047	11,015
Annual Operating Cost Savings ($)	$1,504	$799	$1,322
Annual Rate of Return (%)	5.79%	3.54%	5.18%
Simple Payback (years)	14 years	27 years	16 years

Under typical conditions, skylights in the stock rooms were estimated to have a payback time of 6 to 8 years, depending on the location and the utility rates. However, when the use of occupancy sensors is considered in the simulations, payback times for the added skylights increase to 14 to 27 years.

3.4 Outcomes

Findings from the prototype design process also helped to inform the design charette process carried out with the retail partner (described in detail in Chapter 5). The design strategies developed here by HMG served as a starting point for discussion at the design charette, where more detailed daylighting design options were developed for the retail partner stores.

While HMG has developed a range of daylighting strategies in conjunction with the retail partner, these strategies tend to focus mainly on customer experience, visual quality and the potential for increased sales. Though the concept of daylighting in high-end retail settings is no longer entirely foreign, it remains largely untested. Now that strategies have been developed that will meet the needs and standards of retail clients, it will be important to implement and study these strategies in a wider range of conditions and settings. As experience and use of daylighting in retail grows, it will be possible to further refine daylighting strategies in retail applications to achieve greater energy savings.

CHAPTER 4:
Retail Daylighting Survey

4.1 Design Survey Plan

The goal of this task was to provide the retail partner's management and design teams with a qualitative survey of how daylight is already employed in stores in California, and how it may be either helping or hindering in their merchandizing goals. The survey provided input to the design charette (described in Chapter 5), but is also a stand-alone inventory of daylit conditions in several of the retail partner's California stores.

A secondary goal was to take a more quantitative inventory of the skylights and fenestration, to allow us to recommend a suitable site for conducting the daylight intervention study described in Chapter 6.

The survey itinerary for this task was developed in conjunction with the retail partner to identify stores with known existing daylighting features. HMG staff made preliminary visits to the stores where possible (stores near HMG offices) to ensure appropriateness for inclusion in the survey. In more remote locations, online satellite images (such as Google Maps) were used to confirm daylighting features. In addition to retail partner stores, other retail or non-retail sites were visited to study other approaches to retail daylighting, such as, use of windows, clerestories, skylights or light pipes for display and ambient lighting.

The final itinerary included a total of 26 locations (14 retail partner buildings, and 12 other daylighting examples) over five days from February 25 through February 29, 2008. The survey team included representatives from HMG as well as management and design team representatives from the retail partner.

4.2 Design Survey Activities Summary

The design survey team visited 11 retail partner locations (a total of 14 buildings) that were known to have existing daylighting conditions, as identified by the retail partner's Senior Lighting Designer. The survey team also visited 12 additional locations that use daylighting. While on site, the team observed and recorded the following information:

- Interior and exterior photographs of the skylights and fenestration, and resulting daylit areas
- The materials and construction techniques, and condition of any skylight or window
- Conditions of daylight illuminance inside the store, and any positive or negative effects on visual quality or merchandising
    - For example, attention was paid to issues of glare, sun penetration, transparency from inside to outside, and vice versa, interior and exterior store appearance at

night and on cloudy days versus sunny days, thermal impacts, store navigation, signage, and location and appearance of displays

- The type of electric lighting used in the daylit areas, especially if any different from the rest of the store areas
- The type of products and displays impacted by the presence of daylight
- Any history of the skylights and fenestration that we can obtain from the store manager or facilities staff, and/or challenges or opportunities that they have experienced in relationship to the fenestration

4.3 Survey Itinerary

Design survey location visits were planned as follows:

- Monday, February 25, 2008
    - Retail Partner location, Union Square, San Francisco
    - Bloomingdale's, San Francisco
    - Retail Partner location, Sunnyvale
    - Retail Partner location, Oakridge, San Jose

- Tuesday, February 26, 2008
    - Retail Partner location, Newark
    - Retail Partner location, Pleasanton
    - Retail Partner Men's Store, Walnut Creek
    - Ace Hardware, Martinez
    - Retail Partner location, Fairfield

- Wednesday, February 27, 2008
    - Retail Partner location, Roseville
    - Roseville Mall
    - Scandinavian Designs, Rocklin
    - Raley's Bel Air, Sunrise location
    - Cameron Park Library

- Thursday, February 28, 2008
    - Retail Partner location, Rancho Cucamonga
    - Retail Partner Home Store, Costa Mesa
    - Retail Partner Women's Store, Costa Mesa
    - Retail Partner Men's Store, Costa Mesa
    - Bloomingdale's, Costa Mesa
    - Arcalight Factory and Showroom

- Friday, February 29, 2008
    - Retail Partner Women's Store, Manhattan Beach
    - Retail Partner Men's Store, Manhattan Beach
    - Manhattan Beach Mall
    - Prada and other stores, Rodeo Drive
    - Getty Museum
    - Skirball Cultural Center

A brief summary of the observations from each survey location is included in Appendix C: Retail Daylighting Survey Findings.

4.4 Findings and Opportunities for Daylighting

As a result of the Design Survey visits to retail partner locations and daylit buildings throughout California, the project team identified several strategies to integrate or improve daylighting in retail partner stores. The appearance of daylighting very often contributed to achieving a "fresh" appearance: "clean, crisp, clear and bright." The strategies described below will help to improve the impression and effectiveness of daylighting in retail partner buildings.

4.4.1 Colors of Lightwells

- Description: Using cooler colors in lightwells visibly differentiates the lightwells from the rest of the store
- Visual Benefit: Visual variety and refreshment for customers who stay in the store for a long time. Draws customers' attention to the presence of daylight, which has positive connotations. Draws customers into the store
- Energy Savings: From control of the ambient lighting fixtures underneath the skylight. Cooler paint would slightly increase the amount of daylight reaching the floors underneath the skylights.
- Cost Implications: Cost of paint, possibly the cost of repainting these areas more frequently. Cost of controls. Cost of re-circuiting in retrofit.

4.4.2 Drawing Bulkheads Away From Main Axis Windows and Doors

- Description: Drywall bulkheads are usually 2' from the window, which means that a lot of daylight that could be admitted into the store is absorbed by the bulkhead, or reflected back out of the building. The areas of window above the bulkhead are adding

to the energy load of the store but not contributing any daylighting. The bulkheads could be drawn back several more feet to allow more daylight into the space.

- Visual Benefit: More of the store will "feel" daylit. Smoother transition from bright outside to dark inside, as customers enter the store, makes the store look less dark inside. Need to consider night-time appearance of the store from outside.
- Energy Savings: From control of the ambient lighting fixtures and possibly accent lighting near the windows and doors.
- Cost Implications: Cost of installing drywall instead of tiles in ceiling adjacent to window or wall. Cost of controls. Cost of re-circuiting in retrofit.

4.4.3 Consistent Use of Light-Colored Tiles in Daylit Areas

- Description: Use white tiles in areas adjacent to windows and underneath skylights
- Visual Benefit: Light colored tiles reflect more daylight than dark tiles, so they not only appear brighter but make the ceiling and merchandise appear brighter too.
- Energy Savings: From control of the ambient lighting fixtures in daylit areas.
- Cost Implications: Cost of controls. Cost of re-circuiting in retrofit.

4.4.4 Ambient Daylighting

- Description: Providing a low level of ambient daylighting throughout the store. Daylight could be admitted through tubular skylights or unit skylights. The diffuser material and the final finish of the skylight diffusers at ceiling level would be important to the perceived quality of the installation.
- Visual Benefit: Provides color contrast with accent lighting, but may overwhelm accent lighting at times. Excellent color rendering for all merchandise. Variation in the appearance of the store through the day provides a more natural and stimulating environment for staff. Customers are unlikely to perceive the store as daylit due to high uniformity.
- Energy Savings: From control of the ambient lighting fixtures.
- Cost Implications: New build only. Cost of skylights, cost of any changes required to the roof. Cost of controls.

4.4.5 Daylight Modulation

- Description: Deliberately creating controlled differences in brightness between adjacent areas of the store (possibly FOBs) using overhead skylights. Skylights would be approximately 10′ square at a minimum (per Newark/Pleasanton). Either unit skylights or architectural skylights.

- Visual Benefit: Draws customers to the most distant parts of the store. Customers are likely to perceive the bright areas as being daylit. Provides a great deal of visual variety for customers and staff, throughout the day. Excellent color rendering for merchandise in daylit areas. Will overwhelm accent lighting in daylit areas most of the time.
- Energy Savings: From control of the ambient lighting fixtures and the accent lighting in daylit areas.
- Cost Implications: Cost of unit skylights or architectural skylights, cost of drywall. This need not involve changes to the steel in the roof. Cost of controls.

4.4.6 Orienting Displays Perpendicular to Windows and Doors

- Description: In my cases, display walls have been built immediately in front of windows, blocking the light and creating high contrasts between the remaining visible parts of the window and the display itself. Displays could be re-oriented or otherwise changed to make use of the daylight to display merchandise.
- Visual Benefit: More natural appearance to mannequins, excellent color rendering on merchandise adjacent to windows. More of the store will "feel" daylit.
- Energy Savings: From control of the ambient lighting fixtures and some accent lighting in daylit areas.
- Cost Implications: Cost of controls, cost or re-circuiting in retrofit.

CHAPTER 5:
Developing a Business Case for Daylighting

The economic realities of the retail sector post real-estate and financial collapse in 2008 forced the retail partner and HMG to rethink the structure of the overall retail daylighting initiative. The retail partner was no longer constructing new stores in California, though they continued to develop prototype designs that would serve as their design template for new stores being planned elsewhere in the country including the southwestern states bordering California. HMG and the retail partner identified the need to include daylighting concepts in their prototype store designs following the design survey described in Chapter 4. The goal was to identify daylighting opportunities in new store designs while at the same time identifying means of promoting daylighting in existing stores in California (to overcome the fact that no new stores would open in California in the near future). A design charette was identified as the means for the retail partner, their design teams and the HMG team to exchange ideas on how to incorporate daylighting in the retail design paradigm. While the immediate goal was to develop strategies appropriate for the retail partner, the strategies developed through the charette are intended to have broader appeal to other retailers who can benefit from similar strategies.

5.1 Design Charette Concept

The Daylighting Charette brought together the design, planning, energy management and store design teams for the retail partner along with HMG and subcontractors to brainstorm a range of ideas for incorporating daylighting into the retail partner's newest prototype store designs. The goal of the charette was to provide a plan for next steps in the evolution of daylighting for retail partner stores, and ultimately feed into a document that can be shared with the larger design community on how to integrate daylighting in retail environments.

HMG had made some initial suggestions, and conducted some feasibility analysis for incorporating daylighting into a single-level prototype store design. This included analysis of daylighting related energy savings, daylighting quality and acceptability of various daylighting strategies. Those suggestions are summarized in Chapter 3 and formed the preliminary basis for discussing daylight options during the charette.

Since daylighting involves many aspects of design, a number of perspectives in the process were involved in the charette. The group included key members of the retail partner's design team which included architects, lighting designers, store planners, store designers, and engineering staff along with people familiar with merchandising concepts.

Lisa Heschong and Abhijeet Pande attended for HMG along with Naomi Miller, an experienced lighting professional. Having another outside perspective, of an experienced and innovative lighting designer, helped to further spark and inform the brainstorming process.

5.2 Design Charette Structure

The charette spanned two half-days. On day one, the HMG team presented an overview of retail daylighting options and issues, illustrated with a slide show of a range of daylit retail environments based on and including lessons learned from our design survey task (see Chapter 4), as well as a short primer on energy impacts and daylight availability.

On the second day, the participants were divided into two groups. Each concentrated on one of the two prototype design options – One-level prototype, and Two-level prototype. These two prototypes were chosen to cover the range of retail store designs that are common amongst large retail stores. The retail partner's design, planning, energy management and store design teams participated along with architects working on the new prototypes, and the HMG team.

Both groups presented ideas at end of their group discussions to identify daylighting opportunities, challenges and strategies.

5.3 Daylighting Concepts Discussed at the Charette

A number of advantages and challenges were discussed during the charette as related to daylighting in the retail environment. Below is a quick summary.

5.3.1 Daylight for Vivid and Natural Colors

Daylight is the best possible source of lighting for vivid and accurate color rendition of objects, since it is a full spectrum light source and the one most commonly used in our daily life to judge the appearance of objects. Daylight has a color rendering index (CRI) of 100, which is the maximum that can be achieved by any lighting source. A high CRI of 100 means that all colors will be well represented and most vivid under this source. Furthermore, the balance and presence of all wavelengths in the source mean that subtle colors, especially skin tones and the colors of other natural objects are best compared under daylight.

One of the applications of daylight discussed in detail was incorporating skylights in the changing room to provide an opportunity for consumers to see natural skin tones, and fabric colors as they will be experienced outside of the store.

Note that the color of window glass tints or plastic skylight glazing can shift color perception. Thus glazing materials should be selected to be color neutral to keep daylight perception well balanced. We showed the example of one of the retail partner's skylights that had been retrofitted with a blue-tinted film. This would be a poor strategy for preserving color accuracy.

Figure 10: Daylight Enhances Natural Colors

5.3.2 Daylight for Attraction

Humans are naturally "photo-tropic", for example, their attention is naturally drawn to brighter scenes. Thus, daylight can provide visual nourishment and focus for the consumers in the store. Highlighting areas of interest or attraction is a natural use for daylight, which will usually be brighter than any electric source. Pools of daylight can be used to draw a customer deeper into a store, or into a back wall.

An example is provided in a photograph taken by Lisa Heschong at the Bloomingdale's store in San Francisco, where daylight bounced off of a high wall was used to provide even 'wall wash' to the boys department sign. This sign was clearly seen from far across the store and easily became the focus of attention.

The charette identified daylight opportunities for the walls of changing rooms to be highlighted by skylights placed around periphery of changing rooms as a way to create a similar visual focus as seen in the sign at Bloomingdale's store in San Francisco.

Changing rooms in the prototypes discussed during the charette (and indeed in most large stores) are distributed across the store and are usually in the interior of the store. Highlighting the walls of these changing rooms would provide anchor "events" for visual attraction within the center of the store. The brightly (and uniformly) lit walls would serve as a backdrop for vivid merchandise displays and signage. These bright 'events' would be visible from any place in the store, thus also helping with navigation.

Figure 11: Daylit Sign at San Francisco Bloomingdale's

5.3.3 Daylight for "Wayfinding"

Daylight can be an effective strategy for highlighting sections of the store to provide 'wayfinding' for customers in the store. An example is to provide daylight near entrances to reinforce customers' sense of orientation, and provide emotional emphasis to the indoor-outdoor transition. Alternatively, daylight might be effectively used to highlight corners using windows to get customers' attention to corners of the store otherwise not easily visible from center of store.

Daylighting is very effective at creating linear pathways, marking the primary way to move through a space. For example, this can be done with a linear 'rhythm' of skylights to accentuate the walkway near the high-value merchandise area.

5.3.4 Daylight for "Visual Decompression"

A good deal of discussion centered on the use of daylight for "visual relief" or "decompression" to customers fatigued of walking around in electrically lit indoor environments. A pool of daylight on a sitting bench, and/or an attractive view to the outdoors, can provide momentary relaxation and rejuvenation from intensive shopping.

For employees, a visual connection to the outdoors also provides information about the time of day and season that is important in maintaining a healthy balance. All of the employees who were located near windows or skylights expressed how much they liked their access to daylight and views during the design surveys..

5.3.5 Daylight for Drama and Emotional Resonance

Daylight is inherently variable, varying in intensity and pattern of distribution throughout the day. This variation can work to create more drama and emotional resonance than any stage design. Bright spots of sunlight highlighting merchandize can be magical, partly because of intensity, and partly due to the fleeting nature of the moment. Pools of daylight in displays can create a more "home-like" ambience, and/or seasonally appropriate lighting conditions.

A good example of this is illustrated in Figure 12 where daylight dappled through screens and partitions creates a 'homey' atmosphere for the furniture displays by providing depth of view and a sense of living space.

Figure 12: A "Homey" Furniture Display in Scandinavian Design Store

5.3.6 Working With Skylights

When working with skylights for daylight one must understand some of the benefits and limitations of working with skylights.

One of the best advantages of roof-mounted diffusing skylights is that their daylight performance is independent of orientation. For most retailers a prototype design is developed in a central location and then applied across their market territory. The actual orientation of the plan may vary for each location, thus potentially causing problems with daylighting that is directional and orientation dependent. Using diffusing skylights in such instances provide the most consistent performance across locations.

In a “fancy-box” retail environment, skylights can provide excellent wall wash onto upper horizon vertical surfaces, such as upper store walls or signage. These areas will be brightly lit with very even illumination, and highly visible from quite a distance.

Skylights are best for large pools of light, from 10′ in diameter or larger. A typical unit skylight form 4′x4′ to 4′x8′ can illuminate an area from 200 sf to 1000 sf, depending on a number of design variables. Once skylights are installed in a space, they are essentially permanent. It is not cost-effective to move skylights around the store, as you would do with electric light fixtures (especially spot lights). Thus, skylighting layout should support the basic organization of the store as well as the overall lighting design intentions.

The general rule-of-thumb for good daylighting from skylights is that the higher the skylights are in a space, the wider and more uniform the daylight distribution from the skylights will be. Thus, the best place to locate skylights is usually in the areas with the highest ceilings. Skylight wells and openings should be as wide as possible to allow the daylight to spread over a large area. Skylight wells canted at 45 degrees is a good rule of thumb. Bright white paint on the walls of the skylight wells will help diffuse more daylight into the space.

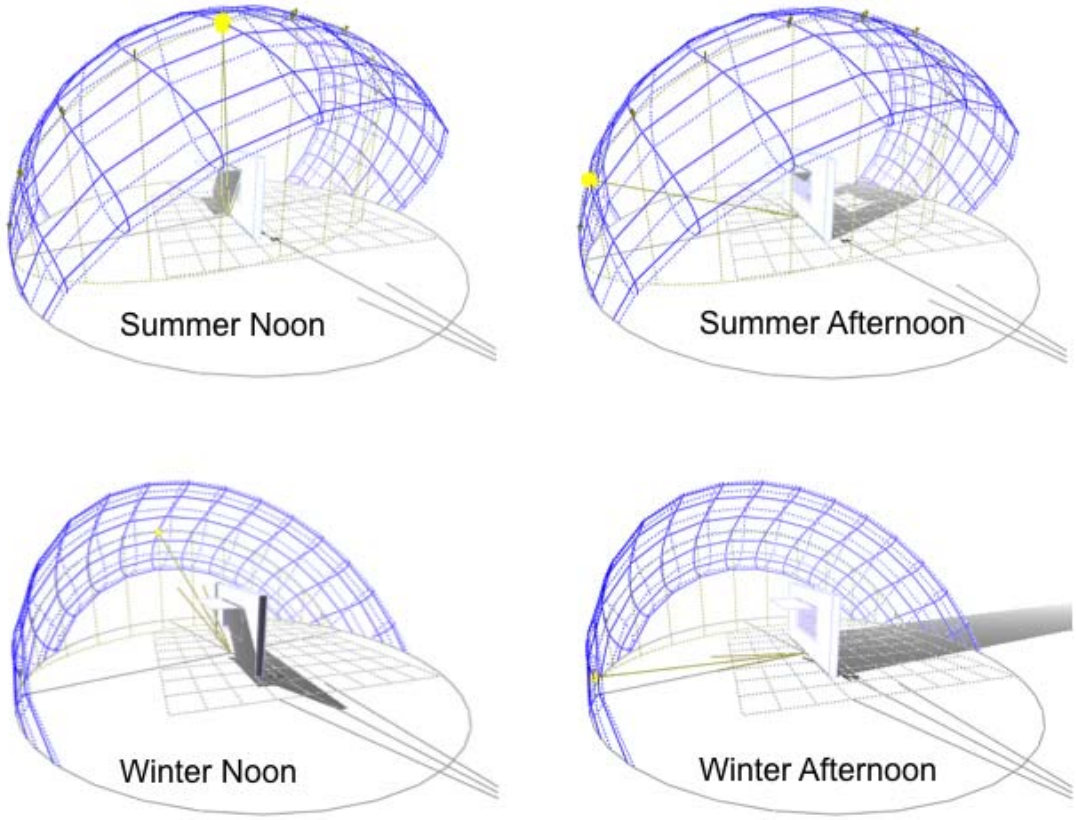
Channeling daylight through deep, narrow openings is generally not efficient or cost-effective. If deep skylight wells are hidden from view (such as by use of a secondary diffuser at the bottom of the well), then specular (shiny) surfaces can help increase the amount of daylight transmitted down through the well. Skylights with specular wells, such as tubular skylights, meant to drive daylight deep through a plenum space, still have limits on how far they can go. A well depth of more than 3 to 4 times the width of the skylight, the loss of light escalates rapidly.

That said, it is also important not to “overglaze.” Architectural designers often have a tendency to prefer monumental skylights to make an “architectural statement” over simple unit skylights which are much more efficient and cost effective at providing controlled ambient illumination. In general, more small skylights strategically located around a space will provide better daylight than a few very large skylights concentrating the daylight in a few overly bright pools.

5.3.7 Working With Windows

Unlike skylights, the quality of daylight from windows is very dependent on the orientation of the window, latitude, and season, as well as surrounding paving and nearby structures. As the sun daily moves from east to west, the presence of direct sunlight and reflected sunlight dramatically change throughout the day and season, with design challenges that also change dramatically.

Figure 13: Variability of Daylight From Windows



As illustrated in Figure 13, the same window facing the same orientation in the same location will receive direct sunlight from different angles depending on different times of day, as well as the season. Understanding sun angles is essential when designing with windows. For prototypes, it is difficult to predict orientations, and therefore difficult to design appropriate sun protection. A variable shading kit-of-parts which can be applied by solar orientation could help address this issue.

In general, allowing direct sun penetration into a sales area is usually a bad idea. Sunlight should bounce off of at least one surface before it reaches people inside the space. This will avoid intense glare and help diffuse the powerful sunlight into more gentle daylight illumination.

For windows providing views to the outside at eye level, controlling glare is paramount. For pedestrians on the outside, controlling reflections will improve visibility to the inside. For shoppers on the inside, controlling glare and bringing in daylight from more than one direction will reduce contrast and silhouetting problems which improve overall visibility.

Trying to control glare via tinted glass is counterproductive, reducing the effectiveness of the daylight. It is better to use diffusing surfaces, translucent screens, and shading devices that more carefully modulate the daylight and create an attractive display area.

High windows will provide the most useful daylight illumination into the space. A general rule of thumb is that the floor area around the window within one head height will be well illuminated, and within two head heights will have some useful daylight illumination.

Daylight from windows is best distributed deeper into the space via matte white surfaces perpendicular and adjacent to the windows, such as ceilings, walls and/or floors. Shiny surfaces can cause more glare. Displays arranged perpendicular, rather than parallel, to windows will have more pleasing daylight with gentle gradients and three dimensional modeling, rather than sharp contrasts and silhouetting.

5.3.8 Working With Electric Light Fixtures

Lastly, but probably most important for achieving the sustainability and energy savings goals of daylighting design, it is critical that electric lights be turned off when they are not needed. This requires understanding daylight patterns, and circuiting the electric lighting appropriately in response.

A good integrated lighting design will ensure that the daylighting provides high-quality illumination during daytime which are then supplemented with electric lights at night and other darker periods. Electric lighting can also be used to provide additional sparkle, or highlights for displays during the daytime.

Daylight and electric lighting are often designed to try to provide the same visual effects day and night. While this is possible, it is difficult to achieve; is often wasteful; and may not be the most effective solution for merchandising. An alternative approach is to allow the appearance of the space to take on a different ambiance during the day and night, creating a more dynamic, and memorable, quality to the space. Much higher levels of illumination are possible with daylight, creating large continuous washes of illumination. At night, lower more intimate levels of illumination are appropriate (and efficient), with smaller points of light creating higher contrast and sparkle.

Electric lighting is most efficient when it is closest to the object it is illuminating. Daylighting is most efficient when it is diffused over a large area, from high locations. Thus, daylighting works best in areas with high ceilings, and big dimensions, and electric lighting works best in smaller, more intimate settings. There are many other fundamental differences in the “nature” of daylight and electric light, that can be exploited by a skilled designer in developing a distinctive visual merchandising look for a store.

5.4 Design Strategies

In addition to over-arching daylighting concepts, specific daylighting design strategies were discussed and developed for the retail partner's prototype store models. Design strategies for the prototype stores focused on the existing features and layout of the prototype designs. These strategies are discussed in detail in Appendix B: Daylighting Design Strategies.

5.5 Outcomes

Overall the charette was an exciting event that provided the opportunity for participants from diverse backgrounds to brainstorm a wide variety of daylighting solutions. It served as a catalyst for further thinking which HMG and the retail partner identified two areas where the charette findings promote the use of daylighting in the retail partners' stores – improving new store prototypes and evaluating daylighting impacts on sales in existing stores.

The charette teams identified several potential solutions to bring more effective daylight into the retail partner's prototype stores as discussed in the previous sections. Most of these solutions could be implemented with slight modifications to the then current prototype design concepts.

5.5.1 Daylighting Intervention Study

The relative cost-effectiveness of the daylighting options identified in the charette cannot be determined without further refinement of details and analysis of costs and benefits. While construction costs are relatively straight forward to estimate, benefits are more difficult to predict. Energy impacts can be estimated once construction details are better known. Improvements to the visual environment can be studied with models, either physical or computer based. Improvements to the shopping experience are the most difficult to evaluate, and are best done by observing real installations that are similar to the proposed designs.

The retail partner has an existing resource of daylit buildings in California, with a wide range of approaches. HMG identified about twenty stores just in California with some significant daylight elements. These can be used as a convenient study ground to better understand impacts and refine design elements. Thus, the retail partner can build on its own experience, along with that of others, to carefully evolve its designs towards a more efficient and successful use of daylight.

With this in mind, HMG and the retail partner designed an intervention study that would evaluate the impact of daylighting in an existing store in California. This study evaluated the impact of daylighting on sales of merchandise as well as qualitative feedback from the store customers and sales associates. The process and findings from the intervention study are presented in Chapter 6.

5.5.2 New Store Prototypes

The most successful aspect of the charette was the adoption of some of the design ideas from the charette by the retail partner and their architectural design team into the prototype designs. The retail partner has opened four new stores in the southwestern United States that feature daylighting features identified and partially developed as part of the design charette. These new stores represent a significant development in the incorporation of daylighting ideas by the retail partner in their 'standard practice' and a major success of the retail daylighting project.

CHAPTER 6:
Daylighting Intervention Study

The goal of the Daylighting Intervention Study was to develop a research plan for conducting a daylighting 'intervention' to study and understand the possibilities for and impacts of introducing daylighting in the retail environment on retail sales and the visual appeal of the retail environment.

The design charette that HMG conducted with the retail partner design team (discussed in detail in Chapter 5) resulted in a number of design strategies to better utilize daylight in a department store setting. However, the relative cost-effectiveness of the daylighting options identified in the charette was not known, and could not be determined without further refinement of details and analysis of costs and benefits. Energy impacts and improvements to the visual environment are difficult to predict without more details. Improvements to the shopping experience are the most difficult to evaluate, and are best done observing real installations that are similar to the proposed designs.

The retail partner had an existing resource of daylit buildings in California, with a wide range of daylighting approaches. HMG identified about twenty stores just in California with some significant daylight elements. These had the potential to be used as a convenient study ground to better understand impacts and refine daylighting design elements. Thus, the retail partner could build on its own experience, along with that of others, to carefully evolve its designs towards a more efficient and successful use of daylight.

With this is mind, HMG proposed to conduct an "intervention study," a field experiment to investigate the effect of introducing natural light as an illuminant on sales, customer behavior, the visual environment, and energy use in a retail partner store. The goal of the study was to provide the retail partner's management and design teams with information on the effect of daylight on customer behavior and potential sales impact specific to the retail partner's store environment.

HMG developed the suggested intervention study methodology, schedule, and reporting format in conjunction with the retail partner to allow for the greatest opportunity for significant findings, while respecting the internal constraints of maintaining and operating a working retail space.

The detailed, quantitative results of the intervention study were made available only to the retail partner, to help guide future decisions on the use of daylight in store designs. Due to the confidential nature of sales data, quantitative data will not be included in this report.

6.1 Intervention Study Design

The goal of the "intervention study" was to validate the sales, customer experience, visual environment, and energy use impacts of introducing daylight as an illuminant in a retail partner store.

Based on the need to carry out the study in a fully operational retail environment there were a number of alternatives considered for carrying out the intervention study. Three different options for "study area" were considered:

- Comparing a daylit store with a non-daylit store
- Comparing a daylit area in a store with non-daylit areas in the same store
- Comparing a daylit area in a store with non-daylit areas in other stores carrying the same or similar merchandise

There were also three options for providing the daylight for the study:

- New construction: building a new daylit store
- Retrofit: adding a new skylight in an existing store
- Retrofit: re-enabling a covered skylight in an existing store

HMG considered a number of different potential study sites in conjunction with the retail partner, based on their existing stores at the time, as well as their plans for future development. HMG discussed the merits of each of the options with the retail partner to determine the most feasible approach for conducting the intervention study.

Ultimately, the retail partner decided that the most informative and successful intervention would be a within-store comparison. There were two physical options for such a study – covering existing skylights, or uncovering previously covered skylights – conditions for both exist within several retail partner stores in California. Based on considerations of feasibility, costs and potential disruption to the affected sales areas, the retail partner chose the option where existing skylights that were previously covered are uncovered as the intervention strategy. By uncovering a specific skylight in the store would allow comparison of the area being studied against other areas of the store where the skylights are still covered and thus have no daylighting.

The in-store comparison was found to be the most advantageous strategy because the retail partner was not planning any new store construction in California in the near future, and there were already a number of stores where original skylights had been covered in subsequent renovations. This approach also allows comparison of customer behavior and the visual environment while the same products, in the same store, are in both the daylit and non-daylit conditions. The complication of this approach is the need to control for variations in weather and economic conditions between the daylit and non-daylit study periods.

In addition, the retail partner agreed to analyze sales or transaction data for the specific area of the store correlated with the lighting changes in the intervention study, and to compare that data to similar departments in comparable stores with no intervention. The analysis of sales data for the study required that sales data from the area affected by daylight could be distinguished from sales in areas not affected by the skylight. Thus, there needed to be near perfect correlation between the proposed daylit area and the grouping of sales data by the retail partner's internal tracking systems.

HMG presented a preliminary list of stores along with potential intervention strategies for each to the retail partner. Given the study criteria, a retail partner store in central California was chosen as the site for this intervention study. The selected store was originally designed and constructed with eight large pyramidal skylights, but skylights in the sales areas were subsequently covered in a store-wide retrofit effort in 1996-1997.

Based on the locations of the covered skylights, the configuration of sales areas in the store, and the retail partner's ability to isolate sales data, a specific area with young women's clothing was selected as the study area for the intervention study. This study area is on the top level of this three-level store. HMG mapped the families of business relative to the skylight location to confirm that the area affected by the skylight could be successfully isolated in subsequent sales data analysis.

6.1.1 Study Schedule

HMG discussed experimental requirements with retail partner's management team to decide on a duration and methodology that minimized disruption while allowing HMG to collect sufficiently robust and useful data. Concerns for timing included having comparable study periods that include a range of climate conditions (sunny and cloudy) while avoiding, or controlling for, seasonal effects.

Initially HMG proposed two pairs of back-to-back study periods which would isolate both seasonal and pre-post effects, as changes in behavior could be observed going both from daylight to no daylight, and vice versa. In general, two weeks was considered the minimum period for any study segment, to include at least two weekends and a range of weather conditions. Thus, assuming no time to change between conditions, a four-period study would require at least two months. Obviously, the promotional context would also be factored into setting the study periods, so that comparable marketing events are included in both conditions.

To conduct the two pairs of study periods though would involve substantial expenses to uncover and recover skylights multiple times. Therefore a revised structure was chosen for the intervention study, one in which there would be a pre-intervention period where the existing conditions with the skylight covered would be studied over several weeks and then the post-intervention period where the skylight would be uncovered and the results studies over several weeks. HMG developed a protocol whereby HMG staff would visit the store multiple times during the pre and post intervention periods to gather relevant information from the store.

6.1.2 Site Data Collection

While on site, HMG proposed to observe and record the following information:

- Weather conditions and exterior daylight illumination levels during the periods of study.
- Conditions of daylight illuminance inside the store, and any positive or negative effects on visual quality or merchandising.
    - For example, attention will be paid to issues of glare, sun penetration, contrasts, shadowing, differences in appearance between cloudy and sunny days
- The type of electric lighting used in the daylit areas, especially if any different from the rest of the store areas.
- The type of products and displays impacted by the presence of daylight.
- Daylight illumination levels in the daylit area, and electric light illumination levels while in the non-daylit state.
- Interior and exterior photographs of the skylights and fenestration, and resulting daylit areas.
- The materials and construction techniques, and condition of, any skylight or window.

In addition, HMG would collect and analyze some combination of the following data:

- Sales data for the daylit area in both the daylit and non-daylit states (using the finest spatial, product and time granularity available from the retail partner).
- Observation-based qualitative or quantitative data on customer behavior in the daylit and non-daylit states. For instance, counts of the number of touches, turn-backs, stops, and items picked up. Observations would be made by HMG researchers either in-person or via video. If available, video data could also be analyzed to record the amount of time spent by customers in specific sections of the store, or their "pass-through" rate.
- Brief interviews or surveys of customers and staff in both daylit and non-daylit states, to determine attitudes and observations.

HMG proposed to conduct two sets of analyses for the intervention study – survey responses and energy savings in the pre and post retrofit conditions. In addition the retail partner agreed to conduct analysis of sales data from the study area by comparing the pre and post retrofit in the study area and comparing them to the control areas of the store as well as other stores in the region.

For the analysis of survey responses, HMG proposed to collect survey responses onsite on paper survey documents and then combine and analyze the survey responses using Microsoft excel and statistical tools.

The energy analysis was proposed to be based on energy simulations using the SkyCalc™ software. Data inputs for the simulations were collected as part of HMG's initial site visits as

described in Section 6.2 of this report. Due to site constraints, it was decided that HMG will not conduct any monitoring of the space using data loggers for energy or lighting.

6.2 Study Site

The store selected for the study was originally designed with eight large pyramid skylights, including one over the central escalator atrium and seven throughout the top level sales areas. The seven skylights over the sales areas were subsequently covered in a store-wide retrofit effort in 1996/97. Only the central atrium skylight remained uncovered. Photos in Figure 15 through Figure 17, below, show the store as it existed in the summer of 2009 before the intervention study, with only the central atrium skylight open, and the other skylights covered with metal roofing and their openings covered by drywall ceilings.

Typical lighting throughout the store consisted of a combination of 2′ x 2′ recessed linear fluorescent troffers and recessed compact fluorescent downlights, interspersed with track mounted accent lighting to highlight featured merchandise displays. Illuminance values vary throughout the sales are, but the average measured horizontal light level was 27 foot-candles, while vertical light levels on merchandise ranged between 50 and 90 foot-candles. Lighting power density in the sales areas is 0.8 Watts per square foot indicating the use of efficient light sources in the store. As is common practice for retail lighting, the light fixtures in the store are controlled on a timer, with the all fixtures in the store turned on during store hours, and some fixtures left on at all times for security, cleaning and other staff activities when the store is closed.

The skylight to be reopened was a 23′x23′ square pyramid, approximately 13 feet tall. Reopening the skylight would create an area of approximately 530 square feet directly beneath the skylight, with at least 1764 square feet of total daylit area.

The study area comprised approximately 8000 square feet of sales area underneath and surrounding the skylight, as shown in Figure 14, below. The control area for the intervention study was made up of the other 40,000 square feet of women's clothing sales areas outside the influence of the re-opened skylight.

Figure 14: Location of ”Study” and ”Control” Areas in the Store

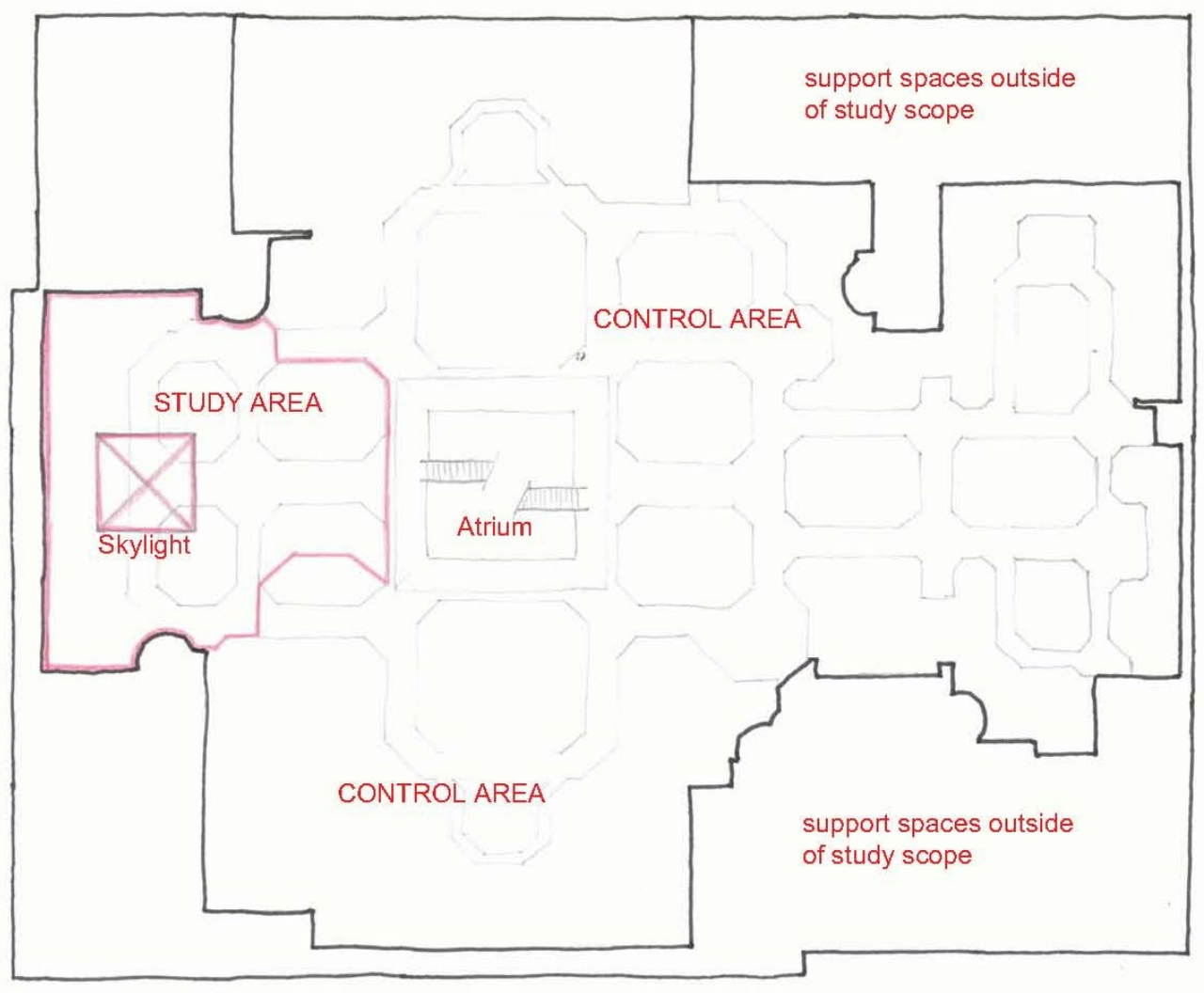


Figure 15: View From Central Atrium (Before Skylight Restoration)

Figure 16: Preretrofit Condition (Dotted Blue Line Shows Original Skylight Location)

Figure 17: Skylight Exterior With Continuous Sheet Metal Cover

6.2.1 Design Details

Details of the design strategies used for the reopened skylight are discussed below in Appendix D.

6.3 Intervention Study Implementation

Following the development of the Intervention Study Design, as described above, HMG worked with the retail partner to oversee the retrofit and ensure that the intervention was carried out in accordance with the design of the skylight, as well as to implement the customer and sales associate surveys.

As discussed in section 6.1, HMG and the retail partner decided on in-store comparison study, where an existing skylight that had been covered would be uncovered, reintroducing daylight into a sales area.

The format chosen for the intervention study was such that there would be a pre-intervention period where the existing conditions with the skylight covered would be studied over several weeks and then the post-intervention period where the skylight would be uncovered and the results studies over several weeks. HMG developed a protocol whereby HMG staff visited the store multiple times during the pre and post intervention periods to gather relevant information from the store. The retail partner conducted the necessary construction and site coordination for the skylight and lighting retrofit in the store and reviewed and approved HMG's in-store survey protocols. In addition, the retail partner conducted analysis of sales data from the pre and post retrofit periods.

The following sections describe the in-store survey design and methodology, as well as summarizing the post-retrofit conditions and in-store survey activities.

6.3.1 Survey Details

Detailed discussion on the survey design and technique can be found in Appendix E: Intervention Study Surveys.

6.3.2 Skylight Retrofit Implementation

As described above, the study involved re-opening a 23 foot square, pyramidal skylight in the young women's clothing section of a retail partner store.

The skylight retrofit was carried out in two phases by the retail partner's facilities and construction teams. The initial phase of reopening the skylight occurred in September and early-October, 2009. Following the initial re-opening of the skylight, adjustments were made to the merchandising in the study area to best utilize the added daylight. HMG staff made visits to

the site throughout the retrofit process to monitor construction progress and the integration of merchandising with the re-opened skylight.

6.3.2.1 Initial Post-Retrofit Conditions

Following the retrofit, the newly re-opened skylight provided a significant change in the daytime lighting conditions in the study area of the store. Shown below in Figure 18, the addition of the skylight provides a distinct visual contrast to the surrounding area. As outlined in section 6.2, the intervention involved re-opening two of the four sides of the skylight (keeping the east- and west-facing sides of the skylight covered to block the low-angle early morning and late afternoon sun), as well as adding supplemental diffusing material to prevent glare. In addition, indirect-direct linear fluorescent lighting was added at the perimeter of the skylight to illuminate the interior of the skylight well and provide general illumination at night when no daylight is available, and additional halogen accent lighting was installed to highlight merchandise displays.

Figure 18: Intervention Study Area – With Skylight Opened

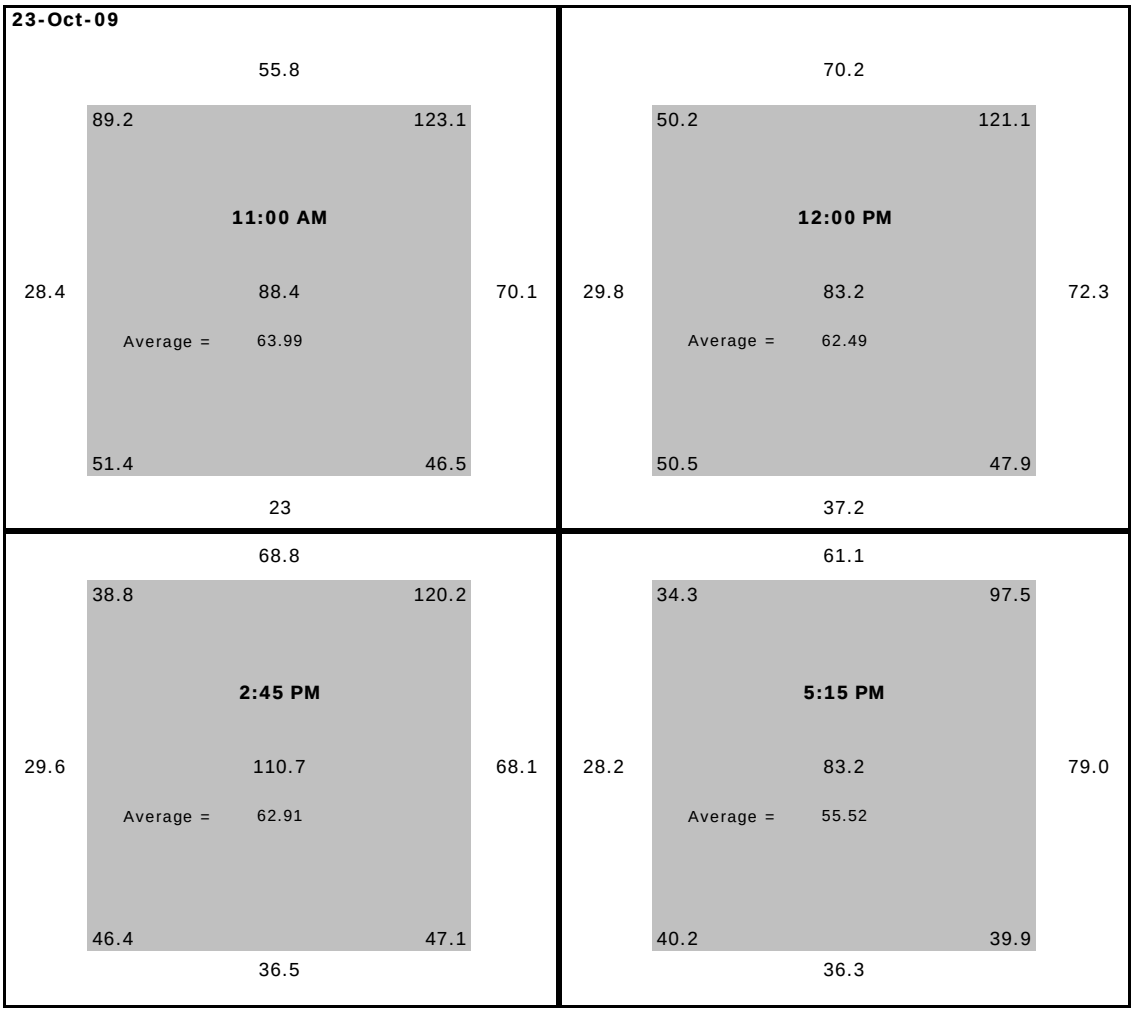
Figure 19: View of Re-Opened Skylight, Showing East- and West-Facing Sides Covered, as Well as Fabric Scrim and Electric Lighting in the Skylight Well

The re-opened skylight resulted in significant changes in the physical lighting conditions in the space. Before the intervention, the average illuminance level on the sales floor was 30 foot-candles. As shown below, in Figure 20, average illuminance levels under, and surrounding the skylight ranged from 55 to 64 foot-candles over the course of the day, during an October 23, 2009 site visit. Values directly under the skylight were as high as 120 foot-candles in some locations. More significantly, the results as seen in Figure 20 show that the daylighting design of the skylight retrofit had succeded in providing high-quality illumination without creating significant contrast between the area directly underneath the skylight versus other parts of the store.

The ratio of maximum illumination under the skylight to average of illumination surrounding the skylit area ranges from 1:1.3 to 1:1.75 while the ratio of the illlumination under the skylight to the lowest illumination level surrounding the skylight was between 1:2 to 1:3. Thus the design features installed in the skylight (see Figure 19) succedded in minimizing chances of glare under the skylight as well as minimizing contrast ratios between the skylit area and the surrounding areas while making a visual impact on that area of the store.

Note that the illumination measurements both under the skylights and the surrounding areas are a combination of daylight and electric lighting.

Figure 20: Diagram of Illuminance



Note: Measurements at four times throughout the day during an October 23, 2009 site visit, at various locations beneath and surrounding the skylight, as well as the average of the nine readings for each time (measurement shown are in foot-candles)

6.3.2.2 Post-Retrofit Obstacles (Oct-Dec 2009)

The additional daylight from the re-opened skylight created distinct a visual attraction to the study area, and daytime light levels in the area surrounding the skylight increased significantly.

However, immediately following the intervention, merchandising decisions and electric lighting control scenarios were not taking full advantage of the new daylighting opportunity. Electric light sources in and around the skylight were not controlled to take advantage of the additional daylight. Halogen track lighting in the skylight remained on despite abundant daylight; and the linear fluorescent lighting around the perimeter, intended to illuminate the fabric scrim and the skylight well at night, remained on during daytime.

In addition, merchandise display pieces and new accent lighting create additional sources of glare during the day and make the ceiling appear dark in contrast. In particular, illuminated light-boxes used to illuminate display features from the side creating distracting sources of glare. Figures below show the conditions in the store after the skylight was opened. Figure 21 shows how the light boxes and accent lighting create glare, and make the ceiling appear dark. Figure 22 shows electric lighting in the skylight turned on despite abundant natural light coming through the skylight.

In order to truly take advantage of the energy saving benefits of the re-opened skylight, electric lighting should to be turned off when daylight is available, and sources of glare should be avoided to prevent visual discomfort.

Figure 21: Circles Highlight Light Boxes

Note: Blue circles highlight the light boxes, track lighting, and surrounding light fixtures creating glare sources during the day. Yellow circles highlight amount of upward light cast onto ceiling by light boxes, making other areas of ceiling seem dark in comparison.

Figure 22: View of the Skylight at Mid-Day, Offering Abundant Daylight, but With Electric Lighting Turned on Below

6.3.2.3 Post-Retrofit Adjustments (April 2010)

HMG worked with the retail partner to mitigate sources of glare in the area surrounding the skylight. The light box display pieces that were creating glare in the space were partially covered with a black opaque material, and in some cases turned off entirely as seen in Figure 23. This significantly improved the visual conditions in the study area.

Even with improved visual conditions, there remain challenges to implement the daylighting-only strategy during the day-time as originally envisioned.

However, electric lighting was still turned on, despite ample daylight, resulting in excessive glare in some cases. Thus there is potential for further refinement and improvements to the electric lighting conditions in the study area. The primary challenge to achieving control of the electric lighting is the cost of re-circuiting existing fixtures to separate fixtures that are to be controlled for daylighting and those that are not to be controlled. Additional research is needed on cost-effective solutions such as wireless sensors and controls that may reduce the cost of daylighting retrofits, but this was out of the scope for this study.

Figure 23: In the Adjusted Condition, Light Box Displays Have Either Been Partially Covered (Foreground), or Turned Off Entirely (Background)

6.3.3 Outcomes

Despite several technical and budgetary challenges, HMG and the retail partner were successful in conducting the daylighting intervention study in the store located in central California. The daylighting design developed by the retail partner in consultation with HMG has succeeded in providing daylight in the study area. Over-illumination was avoided under the skylight along with severe contrast ratios with the other parts of the store. The relatively small budget spent by the retail partner on the daylight retrofit strategy and the resulting daylighting conditions indicates that it is feasible to 'fix' issues with existing skylights in the retail partner's stores that are over-glazed and therefore often covered up to save energy and maintain visual conditions.

The daylighting intervention study process has brought into sharp focus the need for cost-effective solutions to retrofit daylighting controls on existing lighting circuits.

Despite the need for adjustments following the retrofit and some continuing obstacles to achieving the ideal conditions outlined in section 6.2 and Appendix D: Intervention Study

Design Details, HMG and the retail partner were able to obtain valuable results to assess the impacts of the intervention. Although there were challenges in the implementation of the study, introducing daylighting into retail environments is achievable.

6.4 Intervention Study Results

6.4.1 Survey Results

Survey results indicated generally positive responses to the reintroduction of daylight in the study area.

In general, customer survey responses indicated that the addition of daylight in the space increased the attractiveness of the surrounding area and the affected merchandise. While survey responses indicated that customers had difficulty reading signage and product information, control surveys indicate that these problems are pervasive throughout the store and cannot be directly attributed to the reintroduction of daylight in the space.

Sales associate survey results provided a very clear trend towards a more attractive study area where the customers are spending more time, trying on more clothes and an area that the sales associates enjoy more. While there were some complaints from Sales Associates about glare from electric lighting, the skylight was considered a wonderful addition to the space, and received only positive comments.

Detailed discussion of the customer and Sales Associate survey results can be found in Appendix E.

6.4.2 Sales Data Analysis

The retail partner conducted analysis of sales receipts for the departments in the study area compared to the overall women's clothing sales group, and with other stores in the same region. Analysis compared two periods – the 'pre'-retrofit period of October 2008-December 2008 and a 'post'-retrofit period of October 2009-December 2009. For each period, the sales receipts were annualized to a forecasted annual sales figure. Due to the confidential nature of the sales data, it will not be released in this report, but will report on the percentage improvements.

Based on forecasted annualized sales figures, the relative performance of the study area improved +32.9 percent compared to the region, resulting in forecasted incremental sales of 7.8 percent of the annualized sales. However, the control area also outperformed the region. Using the same methodology, the incremental sales for the control area is 5.1 percent of annualized sales. These estimates are statistically similar, suggesting that the addition of the skylight may not have by itself driven the incremental sales improvement in that area.

A better predictor of the daylighting effect may be a comparison of sales in the current period compared to the previous year. A parallel analysis was thus done by comparing the sales in

each of the 'pre' and 'post' periods to sales from the previous year. Analysis of these sales trends for the two areas provides a better correlation to the sales performance. The study area receipts appear to be flat compared to the pre-period trend, but the control area declined 30 percent compared to the pre-period.

Also of interest is the comparison of the study area with just the surrounding department that contains the study area. Receipts in the department within which the study area is contained declined by almost 17 percent, suggesting that sales of similar products declined in other areas of the store, while sales in the study area immediately surrounding the skylight remained relatively flat. Thus the study area outperformed both the overall control area as well as other areas of the department that contained the study area but did not benefit from the presence of daylighting.

While a limited study, this result especially in a difficult economic climate suggests potential for daylighting to improve sales in high-end retail.

6.4.3 Energy Analysis

While increased customer satisfaction and sales were the primary motivations for the intervention study, decreasing the energy use of the store was also an important goal to contribute to the bottom line of store profits. The intervention was designed to realize energy cost savings by taking advantage of daylight to reduce electric lighting use. However, these lighting savings must also be balanced against the skylight's impact on heating and cooling loads.

HMG conducted a series of energy parametric analysis using the SkyCalc™ energy analysis software that generated savings predictions from adding skylights. Initial analysis was done to support the development of the retrofit design, and then a follow-up analysis was conducted to predict annualized energy savings/penalties of the design as implemented on site.

It should be noted, that both these sets of energy analysis made a number of assumptions about existing skylight properties, as well as properties of the proposed retrofit options, and Heating, Ventilating, & Air Conditioning (HVAC) system type and operation. Thus, these are ballpark estimates, and are not designed to be used for system sizing or other engineering decisions.

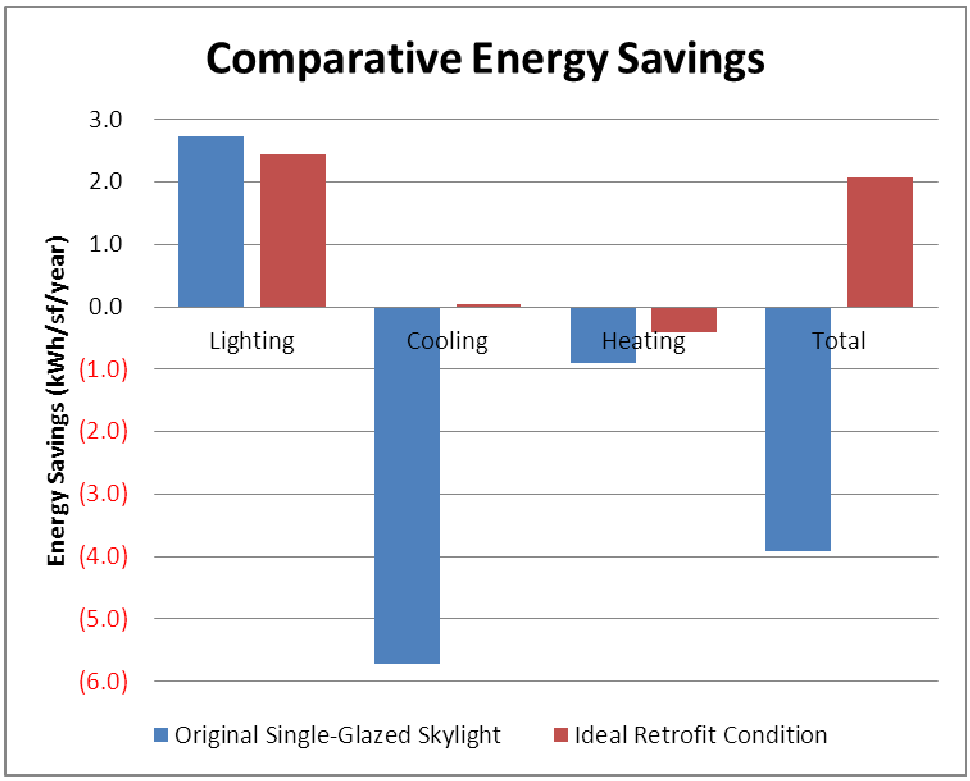
6.4.3.1 Original Design Analysis

During the initial considerations for re-opening the skylight, energy analysis showed that re-opening the entire skylight (even after applying a film to reduce heat gain) would create substantial additional heating and cooling loads that would far outweigh any potential lighting savings. The retrofit study design, described in the Intervention Study Design Report, was devised to reduce the amount of the glazed area to provide ample diffused daylight without creating excessive thermal loads.

Figure 24, below, depicts the comparative energy savings between uncovering the original skylight entirely (blue bars) and the proposed intervention study design (red bars). Both sets of numbers are in comparison to the baseline condition of the pre-retrofit condition (skylight covered). Baseline savings of the pre-retrofit condition is assumed to be zero (in other words, taking no action results in no savings). Positive savings indicate reductions in energy use, while negative savings indicates an increase in energy use.

Lighting savings in this chart assume that electric lighting would be controlled to be turned off when ample daylight was available. As shown in Figure 24, uncovering the original skylight would have created slightly more lighting savings than the proposed retrofit design, but that those lighting savings would have been greatly outweighed by additional cooling and heating loads, resulting in a negative total savings. On the other hand, the proposed retrofit design produces slightly lower lighting savings, but creates only marginal additional loads in heating and cooling, resulting in an overall total savings of 2.1 kWh per square foot per year. The proposed retrofit design was thus chosen to be the most energy efficient option.

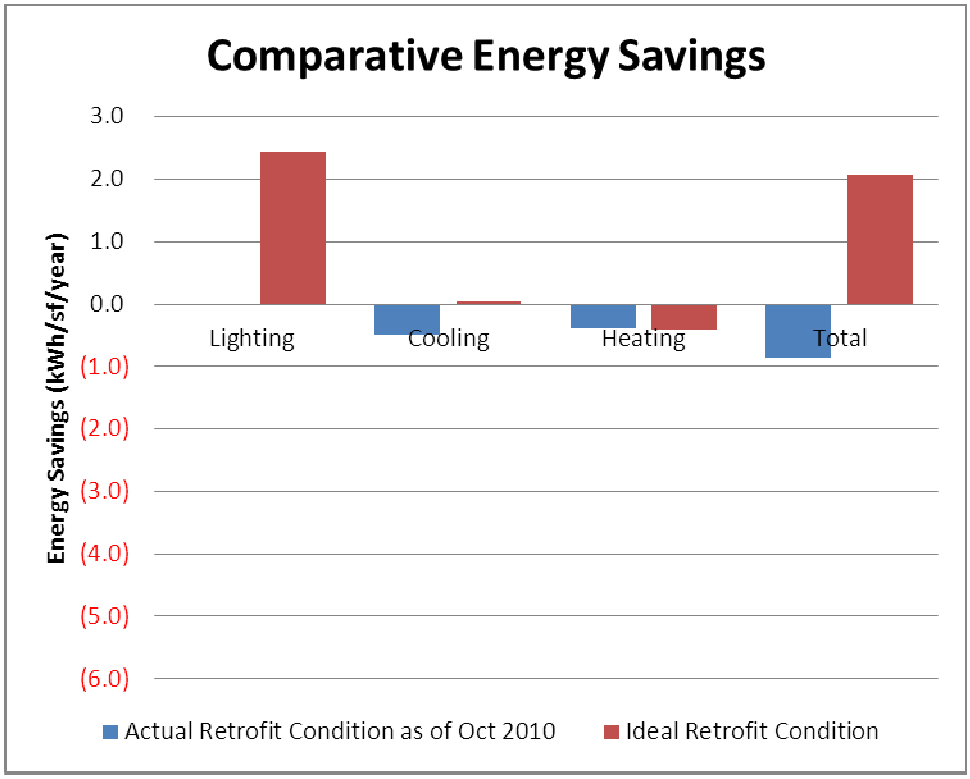
Figure 24: Comparison of Energy Savings Between the Original Skylight Design and the Ideal Intervention Study Design Condition



6.4.3.2 *Current Condition Energy Analysis*

Even though the skylight design has been implemented as designed, the retail partner's store is still not achieving ideal energy savings because the lighting in the area is not controlled to respond to available daylight from the newly re-opened skylight. Figure 25, below, describes the comparative predicted energy savings between the current conditions in the store (blue bars), and the ideal design conditions with controlled electric lighting (red bars). With the lighting in the space not being controlled, all energy savings are not being realized. The added heating and cooling loads resulting from the skylight lead to an overall increase in energy use (shown as negative savings). As shown in Figure 25, rather than realizing an estimated 2.1 kWh per square foot per year in energy savings, the current conditions in the retail partner store is resulting in an annual increase in energy use of 0.9 kWh when compared to the pre-retrofit condition. However, it is important to note that compared to the original skylight, the re-opened skylight is resulting in only a fraction of the heating and cooling loads as a result of the added measures of intervention study design, such as the added film on the skylight, and leaving two sides of the skylight covered.

Figure 25: Comparison of Energy Savings Between the Current Conditions and Ideal Intervention Study Design Conditions



6.4.4 Summary of Results

Analysis of both customer and sales associate surveys show that both groups have a generally positive response to the retrofits described in Section 6.4.1 of this report. Analysis of the sales data for the pre-retrofit and post-retrofit sales trends shows some positive impact of the retrofit as well as described in Section 6.4.2. Together, these two sets of data suggest that the daylighting intervention in the store has been a success.

At the same time, the daylighting design in the store has not been fully achieved due to the electric light fixtures being on underneath and around the skylights. Some of these light fixtures are causing glare and undermine the visual appeal of the store. Further, the light fixtures being on result in additional cooling loads on the HVAC system resulting in the store not saving energy, with the possibility of using more energy than the pre-retrofit condition.

To reduce this energy penalty and to achieve the intended energy savings, it is important that the light fixtures within and surrounding the skylight be turned off during the daytime when there is adequate daylight in the store. Additional work and assistance is needed by the retail partner to evaluate cost-effective daylighting control strategies. These efforts however are outside of the scope of this current project.

While there are still opportunities for continued improvement per above, the intervention study has resulted in quantifiable improvements in the visual conditions of the study area. The intervention study achieved expected results, creating a more attractive retail environment for both sales associates and customers. The intervention strategy chosen for re-opening the skylight has resulted in improved lighting quality that can result in energy savings when combined with the proper controls. The results of the intervention study suggest that similar actions could be taken in other retail settings. Since there are a number of older retail stores in California with inefficient daylighting, there is significant potential for daylighting retrofits in the State.

CHAPTER 7:
Market Connections Activities

7.1 Project Goals

The goal of this project was to encourage, demonstrate and disseminate new approaches to retail lighting design. These approaches seek energy savings and peak demand reduction, while more than satisfying the need of the retail corporation for effective visual marketing and the creation of a highly attractive shopping environment. The intent was to transfer mature lighting concepts such as low ambient lighting as the ideal approach, rather than the current paradigm which is the use of high-energy theatrical style lighting.

7.2 Project Objective

The objective of this project was to engage a major operator of high-end retail buildings (Federated Department Stores), a utility partner, Sacramento Municipal Utilities District (SMUD) and IALD in the development of a new paradigm in lighting quality and energy-efficient lighting in retail facilities. The project sought to achieve its goals through a combination of demonstrations, design assistance, and the development of a new retail lighting method that is energy- efficient and visually-appealing.

7.3 Collaboration With Industry Groups

7.3.1 Collaboration With the International Association of Lighting Designers (IALD)

HMG teamed with the IALD to brainstorm ways to educate lighting designers on the potential for daylighting and impart practical knowledge on how to integrate daylighting in their design practices.

The IALD was chosen as a strategic partner since it is the IALD's vision to promote the field of lighting design and to educate its members on good lighting practices. Founded in 1969 and based in Chicago, Illinois, the IALD is an internationally recognized organization dedicated solely to the concerns of independent, professional lighting designers. The IALD strives to set the global standard for lighting design excellence by promoting the advancement and recognition of professional lighting designers.

Daylighting has been identified by the IALD as a key strategy for meeting sustainability goals, and the IALD agreed to partner with HMG on this project to address strategies to use daylighting in retail environments. A steering committee of the IALD including members from IALD board of directors and prominent IALD members from California collaborated with HMG.

7.3.1.1 IALD Retail Revisioning Webinar

At the start of the collaborative process, HMG hosted a two-hour webcast with invited members of IALD steering committee to brainstorm goals and desired outcomes for this collaborative effort on January 6th, 2009. Ten members of the IALD attended the webinar, while HMG was represented by Lisa Heschong and Abhijeet Pande along with Naomi Miller who was a subcontractor to HMG on the PIER project and also happens to be an IALD member.

During this webinar, HMG presented a high-level summary of the benefits and challenges of incorporating daylighting in retail buildings. Topics covered included the history of daylighting in retail environment, the need for daylighting for energy efficiency, design considerations for daylighting and the coordination of daylighting and electric lighting. The goal of this presentation was to provide an overview of daylighting to the IALD steering committee and set the stage for discussions.

The presentation was followed by a very lively and informational discussion on various aspects of daylighting in retail environments. A key objective for the discussion was to decide on the format and content of a day-long invitation-only workshop to be organized jointly by HMG and IALD on retail daylighting practices and solutions.

IALD members brought up several questions regarding the feasibility of daylighting in the retail environment. These included questions regarding the safety and potential for leaks in skylights as well as fading of merchandise under daylight. HMG provided information on newer factory-assembled skylights that do not leak like the older site-built skylights and provided link to the PIER report of modular skylighting systems for more details on how skylights can be put together. Regarding the fabric fade issue, HMG referenced the IES RP02 Appendix F that deals with this issue and provides guidance on reducing potential for fading through rotation of merchandise and location of merchandise in relation to light sources. HMG further pointed out that merchandise can fade equally under bright and warm electric lighting as under daylighting and the key to reduce fading was to have quality diffused illumination that did not concentrate daylight on any given merchandise for a long time.

The IALD steering committee members also highlighted challenges lighting designers face when dealing with daylighting. Lack of formal education on daylighting principles limits the ability of lighting designers to graph nuances in daylighting designs. Further, lighting designers are almost never involved with a project from the beginning and often are brought into the design process well after the envelope designs are finalized. Thus, they are reacting to existing daylighting in the space rather than thinking about or having input on how to improve the daylighting in the store.

At the end of the webinar, it was decided that a day-long event be hosted by HMG and IALD to provide education to select members of the IALD and seek feedback on future directions for incorporating daylighting in retail buildings. The event would be an interactive event that would seek dialog with prominent lighting designers that have succeeded in using daylighting in their designs. The event would also provide a high-level primer on the opportunities for

daylighting and challenges ahead that require solutions through a collaborative process. It was also decided to invite key non-IALD members such as representatives of the International Council of Shopping Centers (ICSC), building designers and daylighting researchers who have design experience.

7.3.1.2 IALD "Fancy-Box" Retail Design Workshop

Following the webinar with IALD steering committee, HMG conducted a one-day workshop focused on daylighting in "fancy box" retail stores on February 17, 2009. The goal of this workshop was to engage lighting designers, architects and retailers find ways to incorporate daylighting in medium to high-end retail environments.

Twenty people attended this 'invitation-only' workshop hosted by the Pacific Energy Center (PEC) in San Francisco, and co-sponsored by the IALD. Attendees included lighting designers, daylighting experts, representatives from the CEC PIER program and PEC, in-house designers for two California-based retailers, building architects with daylighting experience and a consultant to the ICSC. This diverse group was specifically chosen to represent the range of actors and opinions involved with designing retail stores and thus daylighting in retail stores.

Agenda included a keynote presentation by Lisa Heschong, an interactive daylighting charette with all attendees, forum discussion on next steps for promoting daylighting, and presentations by featured speakers highlighting daylighting opportunities and successes to date.

7.3.1.3 Keynote Presentation

Lisa Heschong delivered a keynote presentation that started by providing attendees with background on the retail revisioning project and the entities that are collaborating on the project. Following that, Lisa presented the rationale for why retail lighting energy use matters in terms of energy efficiency – namely that retail lighting accounts for 37 percent of all retail building energy end uses and retail lighting also has the highest electricity use per occupant of any building type in the US.

Next, Ms. Heschong outlined the key goals for the workshop in the form of the following questions:

- Where are the next big opportunities for daylighting?
- How can we make high fashion and low energy use go together?
- Do we need a paradigm shifts for design of retail stores?
- What are the barriers to greater use of daylighting in retail stores?
- How can we best address them?
- Who needs what information regarding daylighting design?

Daylighting is beginning to gain ground as a strategy to provide high quality illumination while reducing energy consumption through the use of daylighting controls. Many retailers – WalMart in particular – have embraced daylighting for their stores and are now willing share their experiences and specifications for daylighting with others. Due to the Title 24 code and other related efforts, big-box and medium-box stores in California are now required to have skylights if they have high and exposed ceilings.

Most medium to high-end retail stores such as department stores, strip malls and stand-alone stores often have dropped ceilings and thus lower ceiling heights. Also, these stores cannot use the same daylighting strategies as a WalMart that uses skylights to provide uniform illumination in the daylit areas.

High-end retail lighting is about contrasts and visual drama that does not lend well to the uniform diffused illumination concept. Evolving solutions for retail daylighting will involve close cooperation between architects who think their buildings will look beautiful regardless of what light sources are used to illuminate them and lighting designers who are taught how to illuminate dark boxes to create more or less a static illumination scene.

To master daylighting, both of these sets of designers need to learn and understand that daylight is an inherently variable source and the illumination in space is dependent on the movement of the sun in the sky which varies by location, time of day, and season. The designers also need to understand how the solar radiation can be controlled through reflection, diffusion, shading and transmittance based on the needs of a given space and design concept. Lastly, but most important for energy savings, the designers need to have a basic understanding of daylighting control concepts. The key with daylighting controls is to keep the controls very simple to ensure that the controls stay operational as site staff changes and as the store evolves into various uses and layouts.

The keynote also addressed the perception that daylighting can cost a lot of money. Ms. Heschong pointed out numerous examples of retailers using glazing as signage or aesthetic statement that can be easily converted for useful daylighting in the space.

Responding to common misconceptions about skylights leaking, Ms. Heschong presented findings from a previous PIER study on modular skylight designs on how to design a proper skylight. Ms. Heschong also explained that adding condensate gutters and designing proper roof curbs along with using factory-assembled unit skylights will eliminate any concerns about leakage.

Another common misconception about daylighting is the issue of fading of merchandise due to daylight. Ms. Heschong explained that fading is not unique to daylighting but that any light source can cause materials to fade based on dosage and amount of time the material is exposed to the light source. The IESNA RP02 presented in Appendix F provides guidelines on how to avoid excessive fading.

Following these, Ms. Heschong presented some key design opportunities and strategies to consider for retail daylighting. Skylights have a great potential to provide uniform, high-quality

illuminance over a large area of the store. The key is to avoid direct sun-penetration through the skylights through use of diffused glazing or using various surfaces in the skylight well to disperse the sunlight into more manageable daylight.

Working with windows can be challenging due to the potential for glare or silhouetting of objects when looking at bright surfaces behind objects. To avoid these issues, Ms. Heschong highlighted several examples of using screens, diffusing elements to reduce glare as well as positioning merchandise perpendicular to windows to avoid silhouetting.

Next, Ms. Heschong highlighted various possibilities for 'play' and 'drama' through the use of daylighting, that can benefit retail store designs. Daylighting can be used effectively as wall-washes, delineate walkways, provide sense of direction, and highlight merchandise. However, this requires knowledge of where and when the daylight is reaching the store.

The next lesson presented in the keynote was to avoid the mistake of treating daylight as being same/similar to electric lighting. Many designers try to match the color of electric lighting to daylight which is inherently faulty since the color of daylight changes by time of day and season as well as due to local weather patterns. This problem can be exaggerated if the daylight aperture is made to look exactly like an electric light source. The solution is to treat daylighting and electric lighting as two separate but complementary systems. Lastly, Ms. Heschong introduced the daylight charette to the attendees and introduces the featured speakers.

7.3.1.4 Featured Speakers

Following the keynote, several lighting designers and architects presented on their experiences with daylighting, highlighting what strategies had worked and more importantly which strategies had not worked as expected. Bernie Bauer from Integrated Lighting Concepts based in Westlake Village, CA presented work done over the past couple of decades on high-end retail stores by his design practice and highlighted how daylighting has been part of his lighting strategies. Mr. Bauer also highlighted a recent store constructed in the middle-east that uses substantially less wattage for illumination than what the 2008 Title 24 standards started requiring in 2010 (a full two years after this store was built).

Chip Israel from Lighting Design Alliance (LDA) based in Los Angeles, CA presented on the daylighting strategies implemented in the LDA offices in Los Angeles as a showcase for daylighting potential. This office includes a combination of strategically placed skylights over workspaces and conference rooms for general illumination, skylights for wall-wash in the lobby areas, as well as windows in one of the conference rooms that are designed to connect the conference room to an outdoor garden to create an indoor-outdoor space. Mr. Israel also showcased several examples of retail lighting designs that use low installed wattage as well as places where daylighting could perform similar functions.

Homer Perez from McCall Design Group, based in San Francisco, CA presented work done by his architectural design firm for several retail stores that have utilized daylighting to save energy and create a 'fresh' and 'healthy' as well as 'high-end' look in the stores. The work

presented included designs for recently built stores by Pottery Barn, Banana Republic, Smith and Hawken, West Elm, and Elephant Pharmacy as well as several malls. Many of these stores have been designed to meet LEED certification criteria as well as to utilize unit skylights and strategically placed vertical glazing for view, daylighting, or highlighting of certain areas of the store. Patrick Quigley of Patrick B. Quigley and Associates based in Torrance, CA provided a virtual tour of various buildings around the U.S. that have made good use of daylighting for visual appeal and illumination. Among the buildings showcased was a museum in San Diego that uses a significant amount of glazing in a building that incorporates a lot of concrete. The play of daylight through the museum softens the impact of the massive concrete walls and creates a sense of 'play' and 'fluidity' in the space. At the Kia Motors U.S. headquarters, large vertical glazing brings plenty of daylight onto the central display areas as well as to the offices. Use of skylights with attached internal louvers provides high-quality and high-quantity illumination in the design center where illumination levels in excess of 300 fc, are needed evenly on the entire floor – devoid of shadows – so that designers working on new car designs can see all details without dark spots or shadowing of objects. Other examples included works of the Japanese architect Tadao Ando on the use of narrow daylight apertures in thick concrete walls to create wall-washes and 'light-patterns' such as a cross in a church building.

Jeff Shepard of Roth Sheppard Architects based in Denver, CO presented on recent projects completed in California and Colorado that have some very well designed daylighting systems. Of particular interest was the Scandinavian Design store in Rocklin, CA, which was designed with daylighting, as the primary source of illumination. The store uses large display windows to highlight merchandise as with many other retail stores. In this case however, the store has been successful in using daylight to highlight merchandise in the windows by placing interior partitions perpendicular to the windows and thus diffusing the daylight onto merchandise from multiple orientations. Placing the interior partitions perpendicular to the windows also allows the daylight to reach further back into the space which is also aided by white-colored ceilings next to windows that help bounce the daylight into the space. The interior of the store also has a high ceiling where rows of clerestory windows provide ample daylight to the interior of the store, thus reducing the need for using electric light fixtures during daytime.

The keynote and the featured speakers set the stage for a mini design charette that all attendees participated in.

7.3.1.5 Design Charette

The design charette was organized with the goal of identifying how designers and store operators can deal with stores that have daylighting already present and how they can add daylighting to existing stores.

To assist in the design charette, HMG had developed prototypical retail store designs. While the rest of the retail revisioning project focuses on anchor tenants that have large footprints, for this particular design charette two smaller sizes were chosen since they represent smaller stores commonly found in the newer 'lifestyle' strip malls. The smaller stores present both a simpler

design challenge in terms of geometry, but also a much harder challenge due to the fact that they have more turnover than the larger stores and thus the daylighting needs to adapt to various merchandise and display concepts.

The charette was then organized in four teams, ensuring that each team had least one architect and one lighting designer among them. Each team inherited one existing space, from a choice of four types of spaces (two sizes and two layouts each):

- **8,000 sf**
  Linear skylights or square skylights
  80′ x 100′, 20′ x 40′ structural grid, 12′ ceilings, 6′ plenum
- **24,000 sf**
  Linear skylights or square skylights
  120′ x 200′ 20′ x 40 ′ structural grid, 14′ ceilings, 8′ plenum

For comparison and to give some creative ideas, the following table of retail chains with similar sized floor plans was given to the teams:

Table 1: Retail Chains With Similar Sized Floor Plans

Small (8,000 sf):	**Large (24,000 sf)**
Ann Taylor	Banana Republic
Chanel	Brooks Brothers
Gucci	Pottery Barn
Williams Sonoma	Crate and Barrel
Restoration Hardware	Apple

The challenge was to design two very different store layouts for the given space. The goal was to test out how flexible a given skylight layout can be, supporting many alternative design concepts.

The following rules were also given to each of the teams -

- Basic program. Each store should contain:
  - At least three distinctly different types of sales area (for example, clothing on tables, racks, wall display; or glassware, pottery, and furniture)
  - Window displays
  - At least two checkout counters
  - 10-20 percent storage, connected to loading dock

- Exercise rules:
    - "Hard" ceilings in the store can be shaped.
    - Skylight wells can be shaped. Teams have complete freedom with the façade, but should take advantage of daylight
    - Don't mess with the structural grid or existing roof
    - For each design, teams can cover up to 1/3 of existing skylights, and/or add no more than two
    - Sufficient plenum must be maintained for HVAC runs

- Final product:
    - Plan (retail layout with product types and display types)
    - Ceiling plan, with conceptual lighting plan and daylight control zones
    - Sections and/or elevations

Each team was given an hour and half to discuss options and develop final products. At the end of that period, each team assigned one person to explain the design concepts and how they met the design requirements outlined above. Each team was also encouraged to identify challenges and opportunities that they identified during their charette process.

Results from the different teams highlighted some common elements:

- Teams preferred skylights to be closer to the demising walls and the back of the store to provide wall-wash and balance the daylight coming from the store front which was glazed.
- One team added a couple of additional narrow skylights at the back of the store to provide an even wall-wash to the back-wall which made the whole store look brighter and welcoming.
- One team that was designing a high-end boutique store created a fluid ceiling design that took the rectangular skylights present in the store and created a wavy skylight well so that the finished ceiling profile was more artistic and fluid as demanded by the boutique chain. This approach of shaping the skylight well so that daylight from the skylight could be channeled as well as shaped into a different form than the shape of the skylight, was a revelation for all attendees.
- Teams also experimented with covering or controlling daylight from the skylights through the use of louvers, fabric shades and other elements in the skylight well.
- Designing store-front displays so that they did not appear in silhouette was the biggest challenge and one not easily addressed in the time allotted for the charette. One team proposed a light-shelf at the entrance to bounce daylight back into the space and balance some of the contrast between the bright façade and relatively darker interiors.

7.3.1.6 Forum Discussion on Challenges and Next Steps for Daylighting in Retail

Following the design charette and presentations on designs developed by each team, the attendees gathered for a forum discussions on lessons learned, challenges, and next steps.

Several key challenges were identified in bringing daylight into retail stores on a mass scale. The first challenge is that daylighting gets installed during initial construction of store, however, the interiors and lighting conditions for the store are not decided on till much later when a tenant moves in and has to decide on where to install lighting to meet their lighting design intent. Thus it is likely that a tenant would not want as much daylighting or as much overall illumination as is provided by the skylights. Many retail chains use very dark interiors on purpose as a branding strategy and these tenants are most likely to want the daylighting to be 'dimmed' or controlled.

A few possible solutions were also discussed. One would be to not have the skylight itself be installed on the roof, but that provisions are made for future installation of skylights through roof curbs that are pre-installed at time of construction but are covered until the tenant is ready to add skylights. Another option would be to provide louvers or additional controls on the skylights so that the daylight output can be controlled as needed by the tenants.

Daylighting design is truly a multi-disciplinary effort, so no particular discipline takes complete ownership of daylighting design as opposed to electric lighting, which is completely in the purview of the lighting designer. Lighting designers also are brought in too late to the design process to influence the overall design strategies. There is a need for a more collaborative and integrated design process as well as more education of the designers and buildings owners on the possibilities of daylighting.

There is a need for "large picture" reasons for daylight such as equating daylighting with 'green' or 'healthy' as has been done successfully in California with schools. The challenge is how to translate that success to retail buildings. Retailers more so than other building owners are driven by the financial bottom-line and thus designers need to see proof of payback or return on investment (ROI) that they can show prospective building owners and clients. Energy savings will only go so far in convincing retailers to use daylighting. Other benefits of daylighting such as creative opportunities for illumination or other 'green' benefits will play a bigger role in the retail world.

Another possibility discussed was whether the presence of daylighting would be used as a marketing advantage. The current trend in mall designs is to have a more 'open' feel to the mall through what is called a 'lifestyle' mall design. The presence of daylight can be beneficial to that feel and can also be used as a 'green' marketing tool for the mall.

As a starting point, the group agreed that there is a need for retailers and designers to 'feel' the benefits of daylighting by experiencing it. This can be done through tours of existing daylit buildings, however, such buildings are few and far in between. An alternative discussed was to have full-scale mock-ups of retail daylighting that can be installed at regional energy centers where retailers and designers can visit them. Another alternative would be to use digital visualization techniques to create virtual-reality experiences for daylighting.

The group agreed that more collaborative efforts such as this workshop were needed to develop ongoing cooperation between the retailers, designers and daylighting experts. With new construction activity at a standstill due to the economic downturn, more attention is needed on retrofit solutions for daylighting. Existing malls and retail stores need to be targeted for introducing daylighting. To this end, the daylight intervention study that HMG conducted with our retail partner is a good first step.

7.3.1.7 Future Coordination

This successful event provides the basis for future partnerships with the IALD, American Institute of Architects (AIA) and other organizations to promote retail daylighting. HMG will continue to work with these stakeholders to identify further daylighting initiatives. Opportunities include:

- Webcast on retail daylighting to the larger lighting design community
- Conference panels/sessions on daylighting at the IALD annual conference
- Conference panel/session at the Retail Green Conference hosted by the ICSC (International Council of Shopping Centers)
- Better integration of daylighting in codes and standards such as California Title 24, ASHRAE 90.1, IECC and other regional standards.

A long-term goal for daylighting beyond the retail daylighting efforts is to get education of daylighting strategies back in school curriculums for architects and lighting designers. for this long-term goal to be realized there is a need for developing curriculums, calculation tools and educators who can teach daylighting strategies.

7.3.2 Collaboration With ICSC

Founded in 1957, the International Council of Shopping Centers (ICSC) is the global trade association of the shopping center industry. Its 60,000 members in the U.S., Canada and more than 80 other countries include shopping center owners, developers, managers, marketing specialists, investors, lenders, retailers and other professionals as well as academics and public officials.

As part of its mission, the ICSC organizes various initiatives and conferences each year for its constituents. The biggest of these is an annual conference, which gathers thousands of members and provides opportunities for networking and education.

The ICSC launched a sustainability initiative in 2007 with the goal of providing actionable information on strategies and methods to meet the goals of sustainable use of resources during construction and operation of shopping centers. HMG collaborated with the leaders of this initiative to provide information regarding daylighting strategies in retail.

Lisa Heschong attended the annual ICSC conference in May 2008 and participated in the 'ICSC Green Pavilion' within the annual conference that brought together ICSC members with experts in the field of sustainability.

Ms. Heschong gave a presentation titled "Utilizing Daylight in Retail Spaces" that provided an overview to ICSC members on why they should consider daylighting for retail stores. The presentation gave an overview of the energy reasons for why daylighting matters for retail stores but more importantly provided information about lighting quality and impact of sales from daylighting. Ms. Heschong presented findings from previous PIER daylighting studies that showed connection between daylight and retail sales, and examples of successful daylighting in retail from such retailers as WalMart, and various grocery stores in California. The presentation ended with an appeal to retailers to explore the possibilities of daylighting and participate in the retail revisioning process.

After this presentation at the ICSC, members of the ICSC sustainability initiative attended the IALD one-day workshop described earlier in this report. Further informal interactions continued with ICSC members on promoting the use of daylighting in retail stores.

7.3.3 Targeted Presentations

The retail revisioning team gave several targeted presentations during the course of the project to promote awareness of daylighting in retail stores.

Following is a short list of presentations and venues. Full presentations are attached to the appendix of this report.

- IESNA Annual Conference - St Louis - 2007
- Retail Daylighting – Pacific Energy Center - 2010

CHAPTER 8:
Retail Innovation Process

8.1 Introduction

The objective of the Retail Revisioning project is to engage a major operator of high-end retail buildings, and an industry group of lighting designers in the development of a new paradigm in lighting quality and energy-efficient lighting in retail facilities. The project seeks to achieve its goals through a combination of demonstrations, design assistance, and the development of a new retail lighting method that is both energy- efficient as well visually-appealing.

The goal of this task is to provide a retrospective analysis of daylighting integration strategies for high-end retail buildings. This retrospective includes results and findings from the design charette and the intervention study at a high level that address the challenges and potential solutions to bringing daylighting into retail buildings.

8.2 Overview of the Retail Revisioning Project

The Daylighting Plus program is an integrated suite of research programs sponsored by the California Energy Commission's Public Interest Energy Research (PIER) Program that aims to promote better understanding of daylighting potential, strategies and metrics with the aim to increase energy savings from daylighting and associated electric lighting in commercial buildings in California.

The Retail Revisioning project is part of this integrated suite of projects. The project aims to encourage, demonstrate and disseminate new approaches to retail lighting design that will result in greater energy savings, peak demand reduction, and a highly attractive shopping environment to increase sales.

The intent of the project is to make use of daylight for lighting energy savings, and to find other ways to reduce the energy consumed by electric lighting. Daylighting for energy savings is now widely practiced in "big box" retail stores, but the highly uniform lit environment that it creates does not meet the expectations of high-end retailers. This project aims to identify daylighting design strategies that specifically contribute to the visual marketing goals of the retailers, while also offering significant energy savings.

While maintaining these overall goals, HMG and our partners adjusted the original study plans to respond to the significant economic challenges produced by the national recessions starting in early 2008. New construction activity was brought to a halt and few of the tasks were rearranged as outlined in the Chapter 2. Three major initiatives conducted by the HMG led team was developing ideas for incorporating daylighting into new store prototype designs, studying the impact of introducing daylighting into existing retail spaces and conducting a

needs assessment with the IALD on how lighting designers can be better educated about daylighting issues.

Following is a brief summary of the lessons learned from these activities that are relevant to the overall retail sector.

8.3 Lessons Learned

8.3.1 Challenges of Working in High-End Retail Environment

8.3.1.1 Pace of Change in Retail

Daylighting apertures are by their nature permanent in terms of their location. This can pose challenges in the high-end retail environment where the location and type of merchandise displayed for sale can change regularly. It is common for a given area of the retail store to have different merchandise – jeans for example instead of dresses – that requires a different level of illumination or a different illumination design.

Over the life of the building, the space may also have different tenants or the same tenant may conduct extensive renovations and reorganization of merchandise within the store. These necessitate flexibility in the illumination design including the location and directionality of light fixtures.

Even in absence of major renovations, illumination and merchandising display concepts regularly change in retail stores. Given this dynamic environment, daylighting design and location of daylight apertures need to be strategic and allow flexibility to be able to cope with such changes. Strategies such as daylight redirecting devices (fabrics, reflective surfaces, architectural solutions) are critical to ensure that the daylight output can be adjusted to meet the needs of the retail environment in the event of changes discussed above.

8.3.1.2 Organizational Challenges

Perhaps the biggest challenge to maintain the usefulness of daylighting in the retail environment is coordination among the various actors involved in making decisions about merchandise that is sold in stores and how that merchandise is to be displayed and illuminated.

It is common practice for store designers to design the outer envelope based on prototype designs without any further involvement in the decisions about what merchandise is to be sold and how it is to be illuminated in the stores post construction.

Store operators and maintenance staff are responsible for maintaining systems operation but have limited input on merchandising concepts. Merchandising teams are responsible for bringing in the right kind of merchandise to sell and how that merchandise is to be displayed.

Lighting designers are involved in the initial design of the store lighting systems and during major renovations/retrofits. Often another set of experts are brought in to create the visual and

branding concepts within the store that utilize existing lighting designs to meet the demands of the merchandising displays or to work with the lighting designers and interior designers to create the correct aesthetics and performance.

At the initial design stage, there is opportunity for coordination between these different trades to develop solutions that are flexible and can adapt to changing demands of the building space. Currently, common practice is to design the envelope to accommodate a range of lighting and layout solutions over the life of the building. Adding daylighting to the equation brings a set of challenges that none of the current actors are well-versed with. None of these actors currently include knowledge of daylighting design in their repertoire. There is a need for greater education on the appropriate use of daylighting in the retail environment and how each of these actors can play a role in the success of daylighting design.

Once the building is constructed, each of these actors operate mostly independent of each other and at different time periods. Thus opportunities of active coordination between the different actors during the life of the building are minimized. This points to the need for better documentation and understanding of how to work with existing daylighting in the building.

8.3.1.3 Coordination Between Building and Lighting Designers

Lighting designers design the electric lighting systems while building designers are responsible for the building envelopes and thus daylight apertures. These two sets of designers need to work in coordination to make the daylighting and electric lighting designs complement each other.

In reality, the two sets of designers work independently and there is often no direct collaboration between the two on design choices. Lighting designers most commonly come into the design process after the building design has been finalized. Another significant barrier to coordination is that lighting designers lack knowledge of how to work with daylighting. Lighting designers are well-versed with electric lighting that once designed performs to specifications without much change from day-to-day and time of day.

Daylighting on the other hand is inherently variable and the intensity and direction of daylight changes by the time of day and seasons. Lighting as well as building designers both need to be educated on the opportunities and challenges of utilizing daylighting.

8.3.1.4 Retrofitting Daylighting

Retrofitting existing stores with daylight apertures and daylighting controls can have substantial costs. Adding windows or skylights to existing buildings by themselves can have substantial construction costs but they also necessitate other changes to the building envelope, HVAC, and lighting systems to accommodate changes to the building illumination, heating and cooling loads.

Adding skylights for example can require other changes to the roof for structural reasons as well as weatherproofing. These in turn may necessitate changes to the HVAC ducting and other electrical/plumbing in the ceiling to avoid overlap with skylight wells.

Retrofitting daylighting controls can also be challenging since changing or adding circuits requires re-wiring of fixtures as well as necessitate relocation of fixtures.

Another challenge with retrofits is the impact of demolition/construction activities on the normal operation of the store. Construction activity can shut down sections of the store which must be coordinated with various trades involved such as the merchandising, sales, maintenance and store design.

8.3.2 Opportunities for Daylighting

While there are the challenges as identified above for successful integration of daylighting in the high-end retail environment, there are solutions that HMG has identified in partnership with our retail partner and the IALD on how daylighting can be introduced in high-end retail stores. Through a combination of picking the right locations to daylight and using daylighting apertures that can be controlled, daylighting that is appealing and saves energy is feasible.

The work done with these partners has also identified specific research and educational needs that need further attention. Below is a short summary of these opportunities and needs.

8.3.2.1 Daylighting in New Construction

The opportunities for introducing daylighting are easier in new construction when there is opportunity for coordination between the various stakeholders and actors described in the previous section. Working with our retailer partner and IALD, HMG has identified several key benefits of and strategies to bring daylighting into retail stores.

8.3.2.2 Daylight for Vivid and Natural Colors

Daylight is the best possible source of lighting for vivid and accurate color rendition of objects, since it is a full spectrum light source and the one most commonly used in our daily life to judge the appearance of objects. Daylight has a color rendering index (CRI) of 100, which is the maximum that can be achieved by any lighting source. A high CRI of 100, means that all colors will be well represented and most vivid under this source. Furthermore, the balance and presence of all wavelengths in the source mean that subtle colors, especially skin tones and the colors of other natural objects are best compared under daylight.

Figure 26: Daylight Enhances Natural Colors

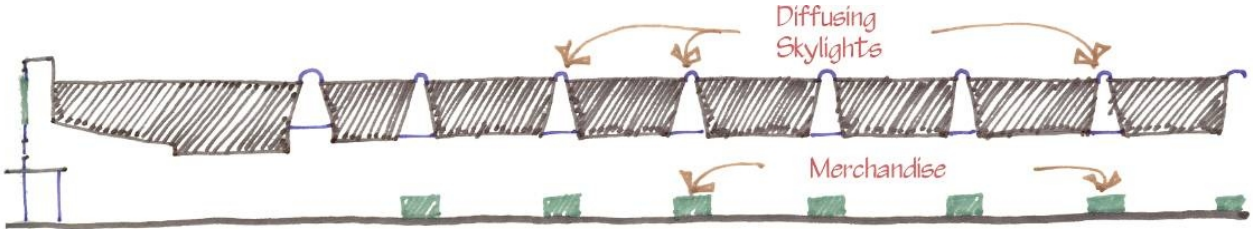
Note that the color of window glass tints or plastic skylight glazing can shift color perception. With this in mind, glazing materials should be selected to be color neutral to keep daylight perception well balanced. One of the applications of daylight discussed in detail was incorporating skylights in the changing room to provide an opportunity for consumers to see natural skin tones, and fabric colors as they will be experienced outside of the store.

Figure 27: Daylit Sign at San Francisco Bloomingdale's

8.3.2.3 Daylight for Accentuating Pathways

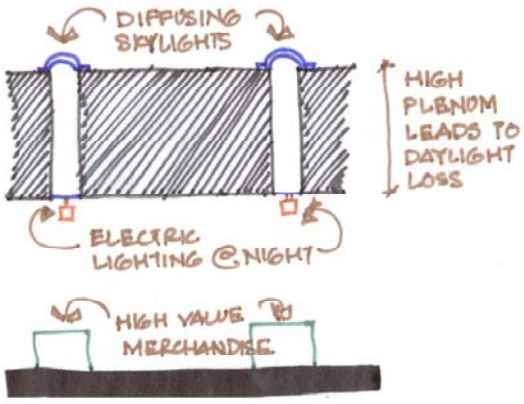
Daylighting is very effective at creating linear pathways, marking the primary way to move through a space. For example, this can be done with a linear 'rhythm' of skylights to accentuate walkways near high-value merchandise areas.

Figure 28: Diffusing Skylights to Accentuate Walkways



The biggest challenge to using narrow skylights is the tall plenum space over the ceiling that is common in many retail stores. Channeling daylight through that depth will result in significant loss of illumination, greatly raising costs and lowering efficiency.

Figure 29: Challenge of Skylights Over High-Value Merchandise Area



One potential solution to overcome this problem would be to design the ceiling layout so that this area has a high ceiling (and thus short plenum space). This would require however that many other design concepts also change. Another, possibility would be to carefully engineer the "light box" design to optimize for daylight integration. Highly reflective surfaces for the skylight wells would result in less light loss from the skylights. This channeled daylight could then be distributed via dropped diffusing boxes that could also be highlighted with electric

light when needed. Another design challenge would be to integrate these long skylight wells into perpendicular distribution of the electrical, HVAC ducting and structural systems. Thus, while this approach is indeed feasible, it would require careful design and coordination to be successful.

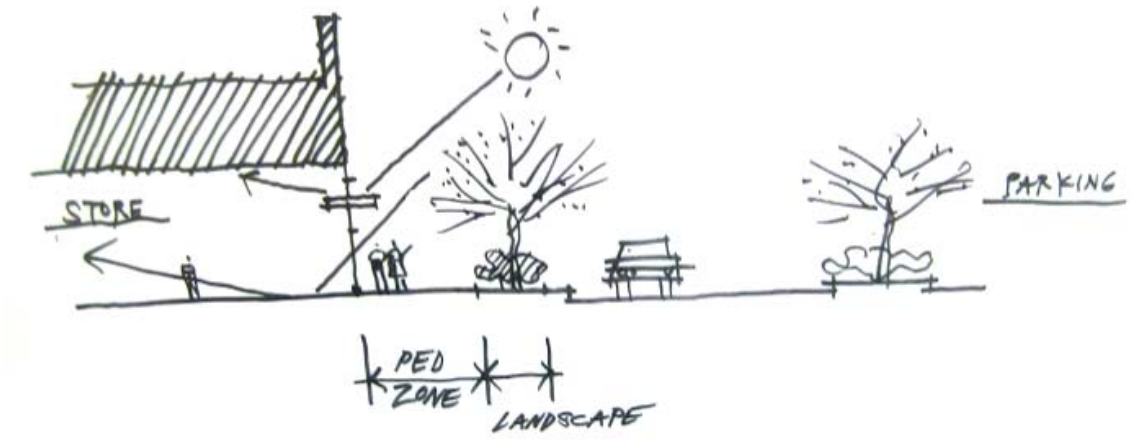
Figure 30: A "Homey" Furniture Display in Scandinavian Design Store

8.3.2.4 Integrating Indoors and Outdoors

A key concept discussed at the charette was how changes being proposed for daylighting might also better integrate the interior of the store with the outdoor environment. In addition to the details for window and entrance designs optimized for daylighting, the group discussed a desire to make the windows and window displays more accessible to customers from both inside and outside the store by moving exterior and interior walkways closer to windows.

Exterior green elements such as trees or shrubs could also be used strategically to reduce glare from sunlight on the windows, and provide an attractive view from the inside.

Figure 31: Connecting Indoors and Outdoors



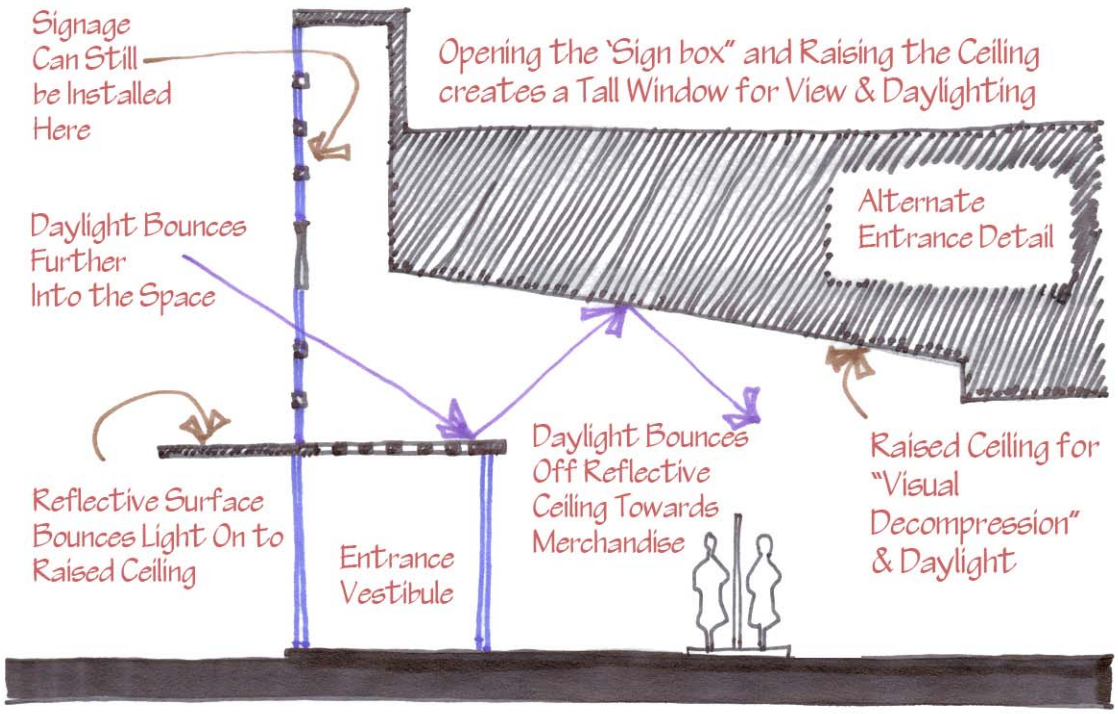
8.3.2.5 Enhanced Use of Daylight at Entrances

Discussions with our retail partner and designers resulted in several strategies to convert the existing glazing in retail stores – primarily the glazing near entrances - into usable daylighting apertures.

A number of retail stores also include significant amount of glazing that is essentially a false façade to highlight signage or merchandize or in some cases as a purely aesthetic statement. These don't add any daylight to the interior of the store since there is usually a dry-wall behind this glazing which renders it useless from a daylighting perspective.

A number of options were discussed to convert these 'sign boxes' into useful daylighting apertures. One such alternative is presented in Figure 32 below.

Figure 32: Detail for Entrance Glazing for Daylighting



Key aspect of this alternative is the raised ceiling near the entrance that redirects daylight further back into the space, and also allows for more expansive views of the outside. The goal would be to bounce daylight deeper into the space, to create a larger area of multi-directional diffused daylight at the entrance. A brighter entrance area, beyond the vestibule, will help create a visual transition area as the customers adjust from exterior light levels to interior light levels. The high bright area at the entrance could also be used for translucent scrim signage visible while entering the store, but which would appear transparent from the other direction.

For a one story store, diffusing skylights located 15-20' from the entrance could achieve similar effects.

8.3.2.6 Improved Window Details

Similar to the entrances, there is often significant amount of glazing on the exterior walls of the prototype store designs. Part of this glazing is for product display windows, but much of the glazing is often only used for signage and/or visual branding purposes. The daylighting challenge is further complicated by the presence of interior display platforms that are often placed right next to the windows which block the windows, creating higher contrast and blocking views to the outside.

Similar to the entrance details, the team discussed ways to raise the ceiling near windows to bounce daylight deeper into the space. Another aspect discussed was the use of semi-translucent panels, such as digital prints, instead of opaque platforms for merchandise displays. These could create a backdrop for the displays, while still letting some daylight and views into the interior.

Other alternatives include adding skylights to balance the daylight from the windows, setting the displays at 90 degrees to the windows, instead of back-to-back, and/or adding perpendicular wall surfaces adjacent to the windows to direct daylight into the space.

Slightly tilting the display window towards the ground, was also discussed as a way to reduce exterior reflections and provide better views from both inside and outside of the store.

Figure 33: Window Detail for Daylighting

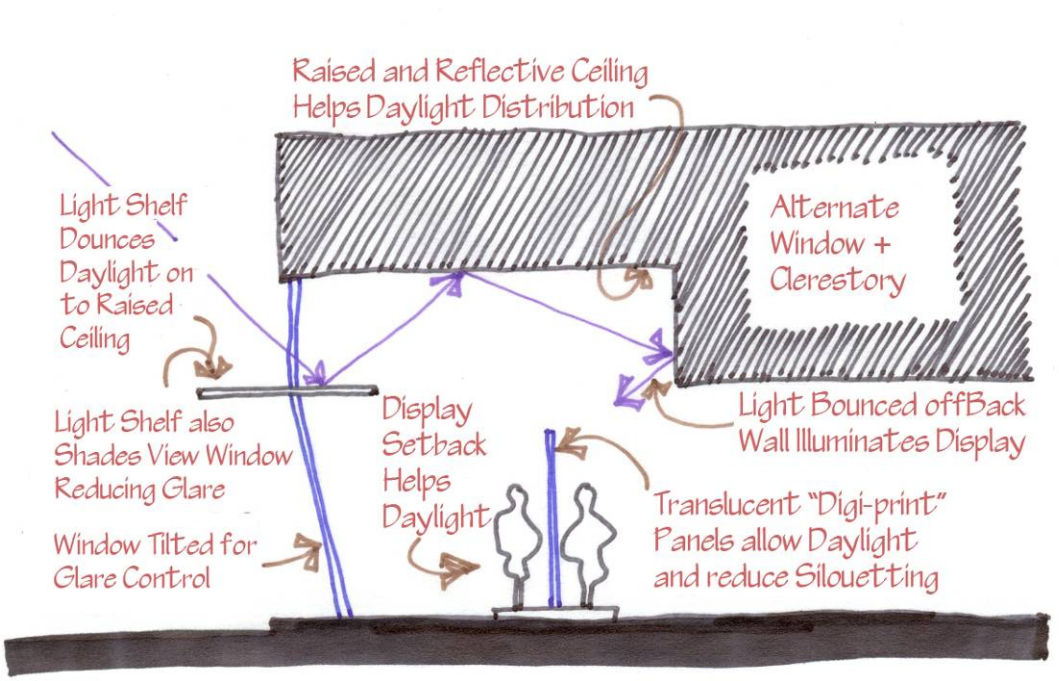
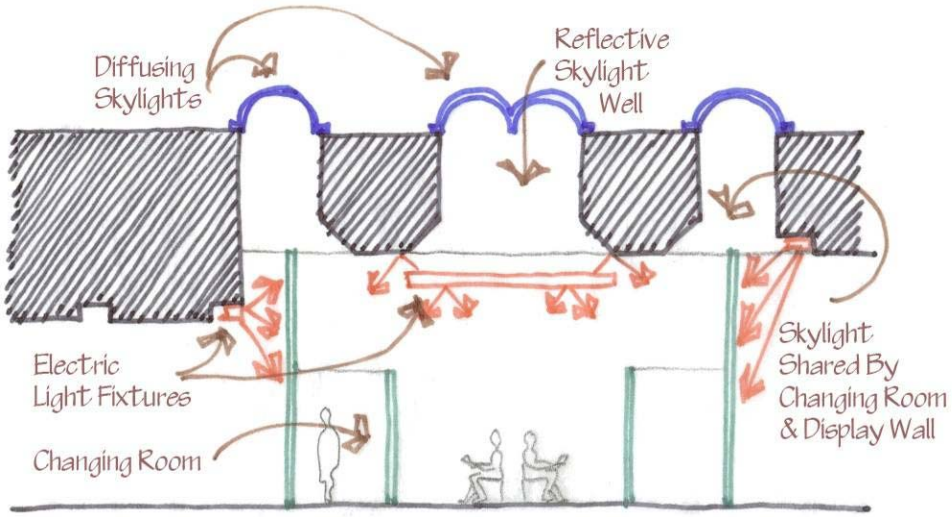


Figure 34: Skylighting in and Around Changing Rooms



The charette identified daylight opportunities for the walls of changing rooms to be highlighted by skylights placed around periphery of changing rooms as way to create a similar visual focus as seen in the sign at Bloomingdale's store in San Francisco.

Changing rooms in the prototypes discussed during the charette (and indeed in most large stores) are distributed across the store and are usually in the interior of the store. Highlighting the walls of these changing rooms would provide anchor "events" for visual attraction within the center of the store. The brightly (and uniformly) lit walls would serve as a backdrop for vivid merchandise displays and signage. These brightly lit 'areas would be visible from any place in the store to also help with navigation.

Another advantage of providing daylight illumination in changing and waiting rooms is that customers can see the real color and texture of garments that they are trying on due to daylight being a high CRI light source.

8.3.2.7 Retrofitting Daylighting

There are several retail stores in California that have existing windows and skylights but which are not optimized for their daylighting potential. The design survey road trip conducted by HMG and our retail partner identified several stores where the windows or skylights had either deteriorated in quality (reduced light transmittance, weather related damage, discoloration) or had been retrofitted with drywall or metal covers that reduced or completely eliminated daylighting potential as described in Chapter 4. Often, the existing glazing tends to be monumental in nature, that is, it is too large for the space it is supposed to daylit and results in overheating the space. A common technique used to combat heat gains in the space due to

monumental skylights is to use composite glazing materials such as plastics, polycarbonates and insulation layers that diffuse the daylight and reduce heat gain. Some of these materials – polycarbonates in particular – are not sufficiently weather-resistant and thus deteriorate physically and become cloudy and or opaque over time. This results in lack of useful daylight, but also creates a visual nuisance.

Based on these findings, the retail revisioning team conducted a daylight 'intervention' study on a store in California's central valley as described in Chapter 6. In this store, the existing skylights were covered during a retrofit in late 1990's with metal panels on the outside and a dropped ceiling on the inside to eliminate any daylighting potential. This was done to combat excessive heat gains from the skylight which was way too big for the space and was single glazed. Working with our retail partner, HMG successfully designed a retrofit strategy where one of the skylights was opened up while measures were added to diffuse the daylight and reduce heat gains. The strategies are explained in detail in Appendix D: Intervention Study Design Details, and include adding window films that reduce solar transmittance, diffusing elements such as fabric panels in the skylight well and opening selective areas of the existing skylight.

The intervention strategy was successful in creating a daylight condition in the space that was visually stimulating to the customers and sales associates and did not add significant heat gains to the space or create glare from too much daylight pooling under the skylight.

There are a number of retail stores in California that could benefit from similar interventions/daylighting retrofits. The key aspects to keep in mind while doing so are:

- Minimize solar gains through addition of shading elements or low solar heat gain films
- Diffuse daylight coming through the skylight through diffusing membranes or fabric suspended in the skylight well.
- Minimize high contrast ratios between the daylight under the skylight and the surrounding areas without daylight. This can be achieved via diffusion of daylight and by controlling the amount of skylight/window that is to be opened for light distribution.
- Control the fixtures in and around the skylight/window to be controlled so that they can be off or dimmed during daylight hours to get energy savings.

8.3.2.8 Lighting Controls

One significant issue identified during the intervention study was the challenges (costs, logistics) of adding/changing lighting circuits and adding controls to existing light fixtures in the space. Adding daylighting controls is a critical component of achieving a successful daylit design and without these controls there may be an energy penalty to the store rather than energy benefit. Using traditional wired circuits and controls can be expensive and require significant time and coordination among the store staff and construction crews.

Wireless lighting controls could be potential solution to this problem since they don't need new wiring to be added or existing wiring to be removed or re-circuited. The field of wireless controls however is still relative new and there is a need for further field studies and cost-effectiveness analysis before retailers can begin to trust this new technological solution.

8.4 Next Steps

8.4.1 Continued Education on Daylighting Design

Lack of knowledge of how to design buildings to include daylighting and how to design electric lighting to respond to that daylight are significant obstacles to daylighting retail buildings.

Limited, if any, information regarding daylighting is available to lighting designers as part of their formal training and work experience. Conversations with the IALD and other lighting professionals identified the need for formal education on daylighting strategies. Daylighting, like other architectural solutions, does not lend itself to a set solution that can be copied as-is across buildings and locations. Daylighting strategies need to be grounded in the needs of the individual building, its location and climate. Thus, education on climate, especially the movement of the sun and its impact on solar gains and illumination in space is critical to achieve a good daylighting design.

HMG has developed a first-step solution through contents for a 'wiki' page on daylighting that can be used by the IALD to provide introduction on daylighting to their members. The intent is to provide lighting designers with an understanding of the basic concepts of daylighting and planting the seeds of greater curiosity with daylighting in retail.

This is a good first-step but there is need for a sustainable long-term effort that would require significant coordination between educational institutions, lighting professionals, building designers and daylighting researchers.

8.4.2 Future Research

As outlined in the previous section, further studies are needed on daylighting control options for retrofitting daylighting into existing retail stores. Wireless controls are promising but too new of a technology to be adopted directly by retailers. Demonstrations of the feasibility and cost-effectiveness of wireless controls are needed to convince retailers and lighting designers.

The daylight intervention study conducted by HMG for this project focused on skylighting solutions. Similar intervention study is needed for sidelighting applications of daylighting to show retailers that introducing daylighting through windows is feasible and beneficial.

The current retail-revisioning project achieved initial success in showing correlation between presence of daylighting in the high-end retail environment with positive responses from customers and sales associates. However, the study could not fulfill its original goals of

monitoring daylighting and energy usage in new construction due to changes in the commercial retail construction that eliminated most, if not all of new construction in California.

Through partnership with our retail partner, HMG has been successful in developing daylighting strategies that have been adapted into prototype store designs with a few stores being built outside of California. Stores built on this prototype design will eventually be built in California once construction activity resumes in the state. At such a time, a follow-on study to evaluate effectiveness of the daylighting strategies would provide critical feedback to the retail partner as well as other retailers who can benefit from daylighting strategies.

CHAPTER 9:
Glossary

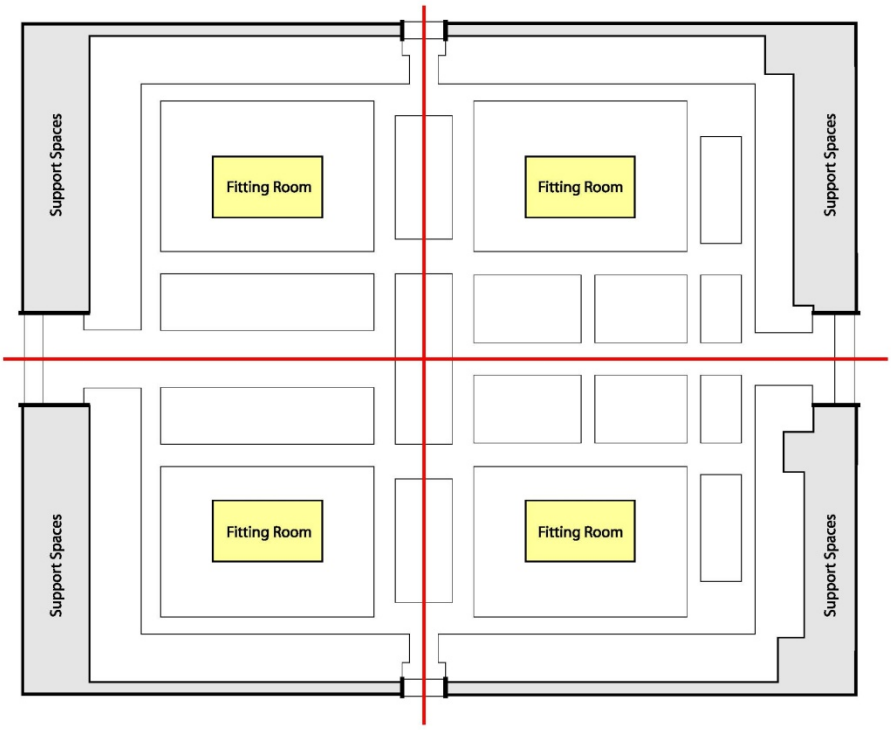
AIA	American Institute of Architects
CRI	Color Rendering Index
FDS	Federated Department Stores
HMG	Heschong Mahone Group
HVAC	Heating, Ventilating & Air Conditioning
IALD	International Association of Lighting Designers
ICSC	International Council of Shopping Centers
IESNA	International Engineering Society of North America
LDA	Lighting Design Alliance
PEC	Pacific Energy Center
ROI	Return on Investment
SMUD	Sacramento Municipal Utilities District

APPENDIX A:
Prototype Store Designs

A.1 Single-Level Stores

The single-level prototype store is envisioned to be part of the new trend toward 'lifestyle centers' where individual stores are smaller, single level and part of a 'neighborhood' of stores. The prototype has a 120,000 square-foot rectangular floor plate. A diagram of the typical single-story prototype plan is shown below in Figure 35.

Figure 35: Diagram of a Single-Story Prototype Layout



Key features of the single-level plan include:

- Four entrances located on two central axes running through the middle of the store. The main customer walkways are aligned in a semi-cruciform along these central axes.
- Secondary walkway runs around the periphery of the store to ease navigation through the store.

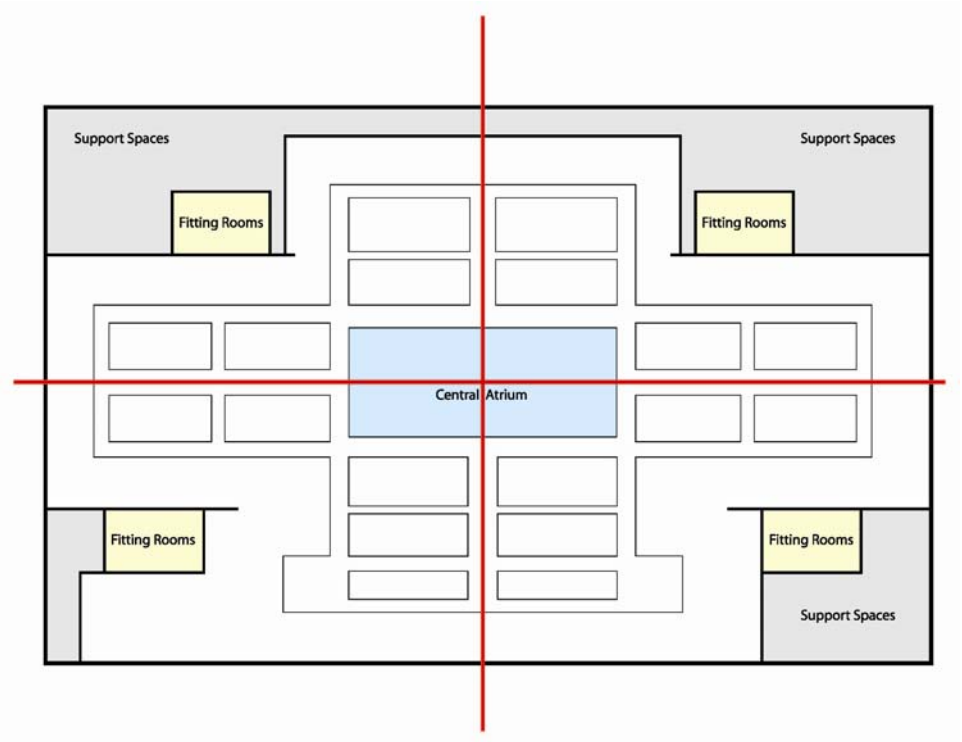
- High-value merchandise, such as jewelry, runs along the main axis of the long dimension of the store. This area has the second-lowest ceiling in the store, while the walkways on either side of this product display area have the highest ceilings in the store.
- Four fitting rooms provide solid "anchors" for each quadrant, and these have high ceilings.

A.2 Two-Level Stores

There are two versions of the two-level prototype designs: 150,000 square feet and 180,000 square feet in size. Both prototype sizes divide the total retail area almost equally between the two floors.

The two-level prototypes retain the cruciform entrances and walkway axes from the one floor prototype. In addition, there is a central escalator shaft that connects the two floors physically as well as visually. A diagram of the typical layout of the two-level prototype is shown in Figure 36, below.

Figure 36: Diagram of a Typical Two-Story Prototype Layout



APPENDIX B:
Daylighting Design Strategies

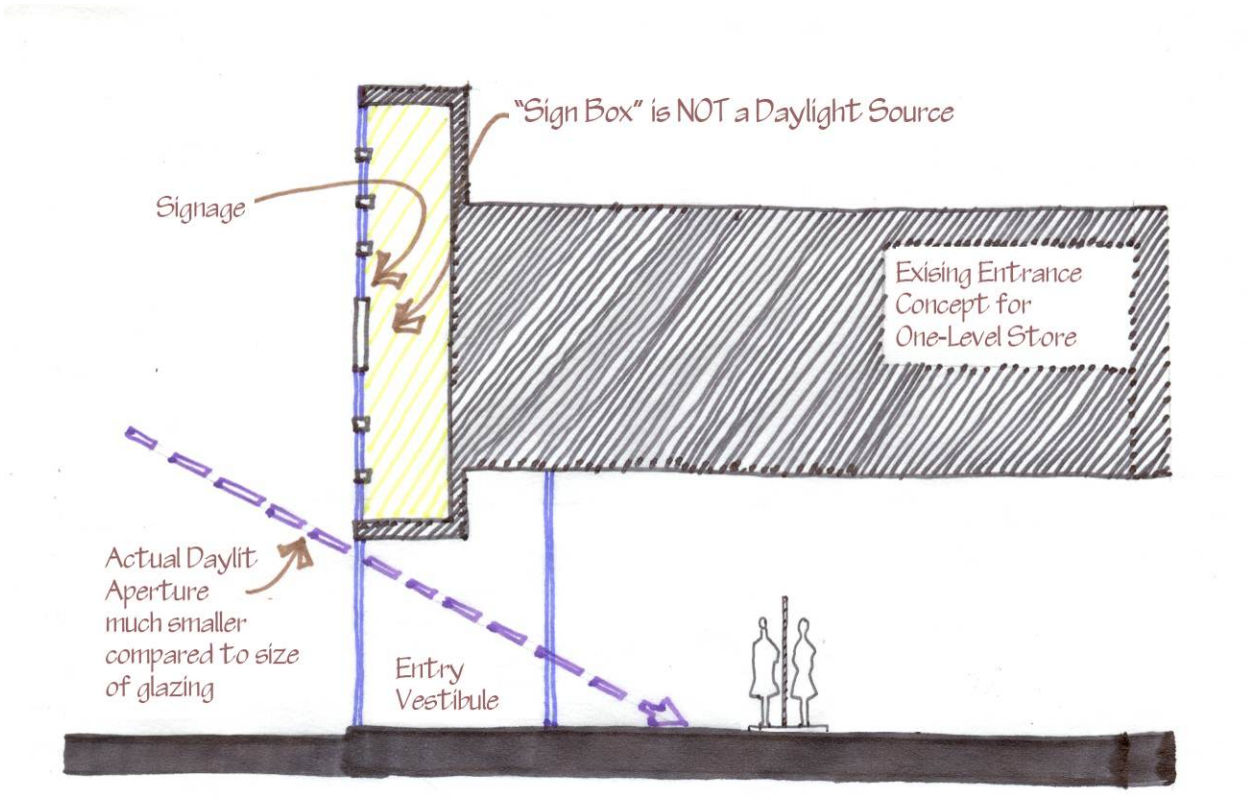
B.1 Strategies for the Single-Level Prototype

The charette group that discussed the one level prototype started with a prototype design that is a medium sized retail store and one where there is a large volume of space with relatively low ceiling heights and limited daylighting apertures.

B.1.1 Existing Daylighting and Missed Opportunities

The one-level prototype designs commonly found in the country often utilize a fair amount of glazing at the entrances, as well as some picture windows for displays or for exterior aesthetic reasons. However, most of this glazing is often not utilized for daylighting because the glazing near the entrances is used for signage, and not for daylight transmission into the space. An example used for the charette is shown in Figure 37 below.

Figure 37: Existing Glazing at Entrance in One-level Prototype

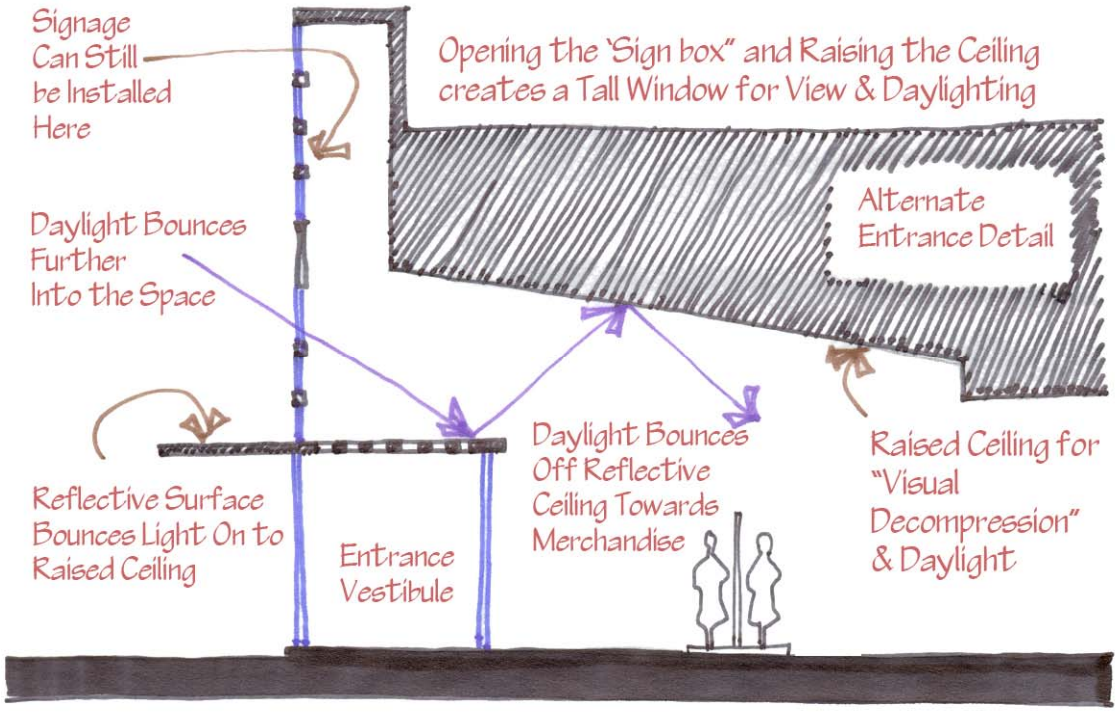


This 'sign box' near the entrance is often used as an iconic branding statement for the retailer, and give the appearance of transparency, but the details of this glazing prevent it from providing useful daylight into the store. It is commonly designed as a giant "cabinet sign" with an opaque back for reflecting light back out the glazing.

The glazing for windows is equally for visual branding of the physical store structure, and is used for merchandise display. However, current retail designs transmit little daylight and may cause more, not less, electric light to be used in its vicinity, to fight excessive contrast, highlight silhouetted objects or compete with higher ambient illumination levels.

B.1.2 Enhanced Use of Daylight at Entrances

Figure 38: Alternate Detail for Entrance Glazing for Daylighting



An alternative section developed and discussed during the charette combines several strategies illustrated in Figure 38 to convert the "sign box" into usable daylighting aperture.

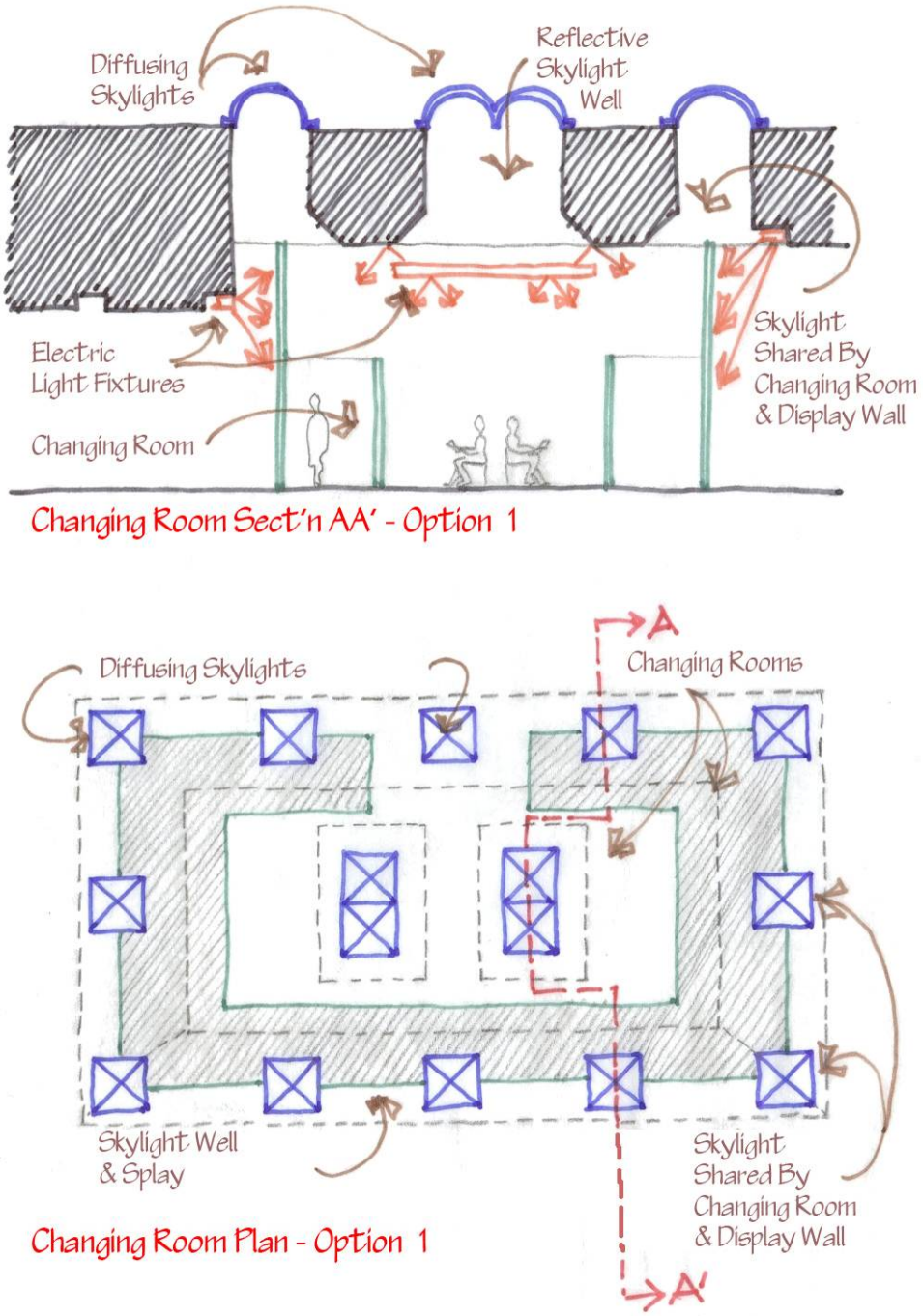
Key aspect of this alternative is the raised ceiling near the entrance that redirects daylight further back into the space, and also allows for more expansive views of the outside. The goal would be to bounce daylight deeper into the space, to create a larger area of multi-directional diffused daylight at the entrance. A brighter entrance area, beyond the vestibule, will help

create a visual transition area as the customers adjust from exterior light levels to interior light levels. The high bright area at the entrance could also be used for translucent scrim signage visible while entering the store, but which would appear transparent from the other direction.

For the one story prototype, diffusing skylights located 15-20′ from the entrance could achieve similar effects.

B.1.3 Skylighting in Changing Rooms

Figure 39: Skylighting in Changing Rooms



The one-level prototype store has changing rooms located in the interior of the store. The charette group proposed design options for skylights over and surrounding the changing rooms. In addition to providing ambient illumination for the changing room and waiting area, skylights will enable customers to see the 'real' color of garments that they are trying on. Skylights could also provide greater drama into the central area, and daylight into the changing rooms themselves. By sharing a ring of skylights around the changing rooms with the exterior walls of the block, the high walls of the block will be visible from around the store floor, with excellent bright wall-wash highlighting any merchandise display on those high walls.

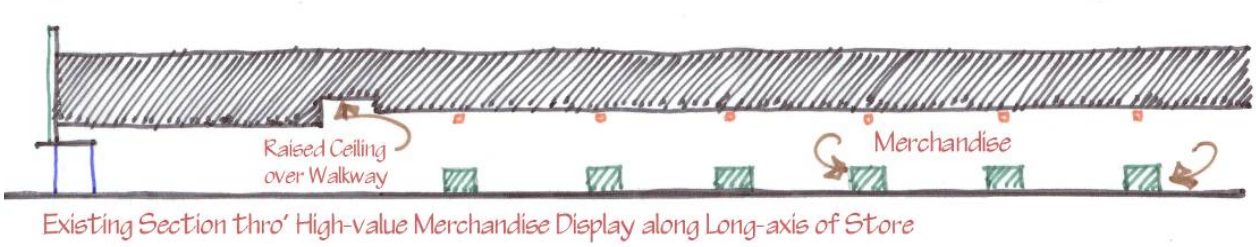
Details that still need to be worked out include the exact dimensions of the skylights as well as the number of skylights needed to provide the necessary lighting effects. It is important to select the correct size, position, transmission and diffusion of the skylight elements to get the desired effects.

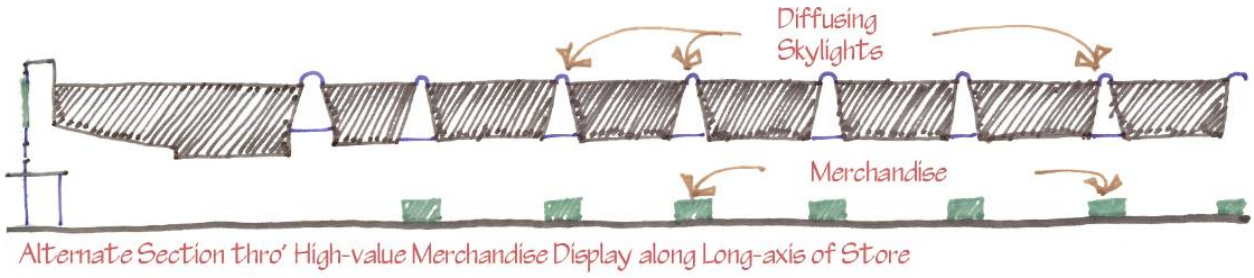
B.1.4 Diffused Daylighting Over High-Value Merchandise Area

The primary design "event" in the prototype store is the central area for high-value merchandise running from main entrance through the center of the store along the long axis of the store. The original electric lighting design for this area was to provide narrow horizontal bands of lighting along the ceiling perpendicular to the flow of traffic. These bands of lighting generate a "visual rhythm" that frames the view of the central display area and accentuates the walkway.

During the charette, the team discussed opportunities to provide similar effect through narrow skylights providing diffused illumination over the merchandise display area. In a way, the horizontal bands are trying to imitate diffusing "light pipes" that could be supplied with daylight.

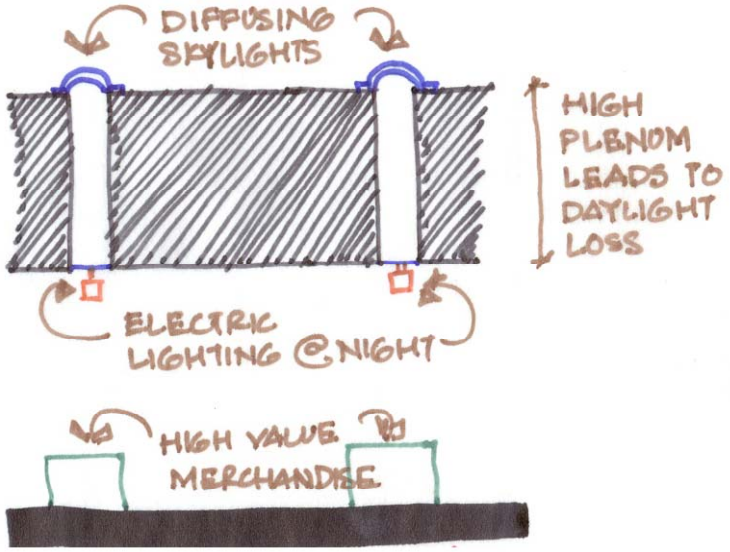
Figure 40: Existing and Alternative Section Through High-Value Merchandise Area





While this approach is feasible, the skylight design needs to overcome significant challenges to be effective, as shown in Figure 41 below. The biggest challenge is the tall plenum space over the ceiling in this display area. Channeling daylight through that depth will result in significant loss of illumination, greatly raising costs and lowering efficiency. In general, daylight is best utilized in the areas with the highest ceilings, not the lowest.

Figure 41: Challenge of Skylights Over High-Value Merchandise Area



One potential solution to overcome this problem would be to design the ceiling layout so that this area has a high ceiling (and thus short plenum space). This would require however that many other design concepts also change.

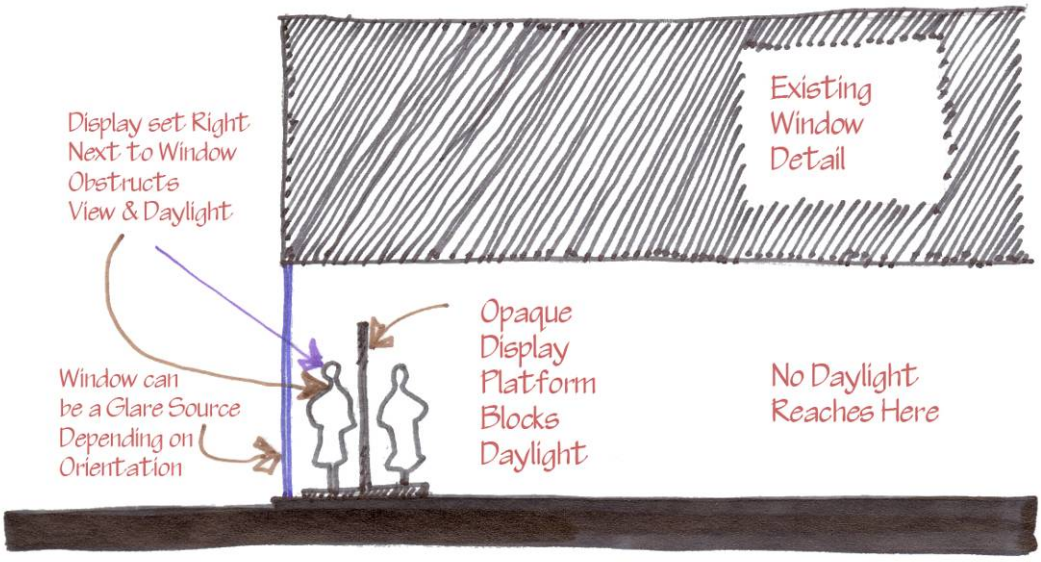
Another, possibility would be to carefully engineer the "light box" design to optimize for daylight integration. Highly reflective surfaces for the skylight wells would result in less light loss from the skylights. This channeled daylight could then be distributed via dropped diffusing

boxes, or a diffusing "blade", that could also highlighted with electric light when needed. Another design challenge would be to integrate these long skylight wells into perpendicular distribution of the electrical, HVAC ducting and structural systems. Thus, while this approach is indeed feasible, it would require careful design and coordination to be successful.

B.1.5 Improved Window Details

Similar to the entrances, there is often significant amount of glazing on the exterior walls of the prototype store designs. Part of this glazing is for product display windows, but much of the glazing is often only used for signage and/or visual branding purposes. The daylighting challenge is further complicated by the presence of interior display platforms that are often placed right next to the windows which block the windows, create higher contrast and block views to the outside.

Figure 42: Existing Window Detail

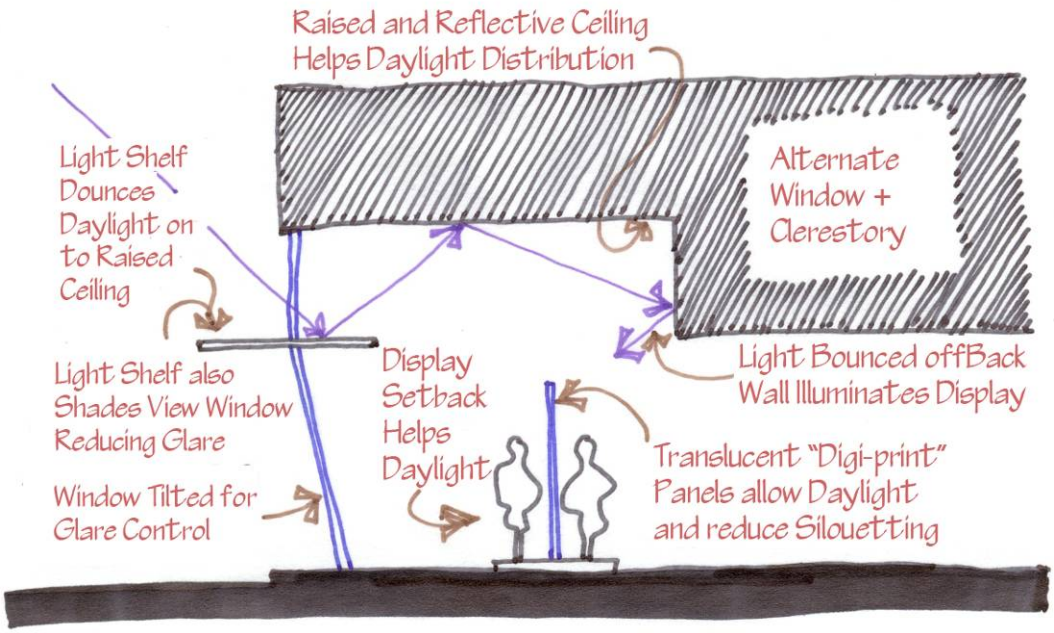


The charette team discussed a variety of ways to overcome these daylighting challenges. Similar to the entrance details, the team discussed ways to raise the ceiling near windows to bounce daylight deeper into the space. Another aspect discussed was the use of semi-translucent panels, such as digital prints, instead of opaque platforms for merchandise displays. These could create a backdrop for the displays, while still letting some daylight and views into the interior.

Other alternatives include adding skylights to balance the daylight from the windows, setting the displays at 90 degrees to the windows, instead of back-to-back, and/or adding perpendicular wall surfaces adjacent to the windows to direct daylight into the space.

Slightly tilting the display window towards the ground was also discussed as a way to reduce exterior reflections.

Figure 43: Alternate Window Detail for Daylighting



B.1.6 Skylights Over Visual Display Platforms

In addition to the skylights over the changing rooms, and the central high-value merchandise display areas, the charette team also discussed the merits of incorporating skylights at strategic locations such as over visual display platforms that are often used to highlight specific merchandise. Because these locations are often fixed and strategic, they suggest a good location for a permanent skylight feature that could be optimized to highlight a three-dimensional display area on a raised platform.

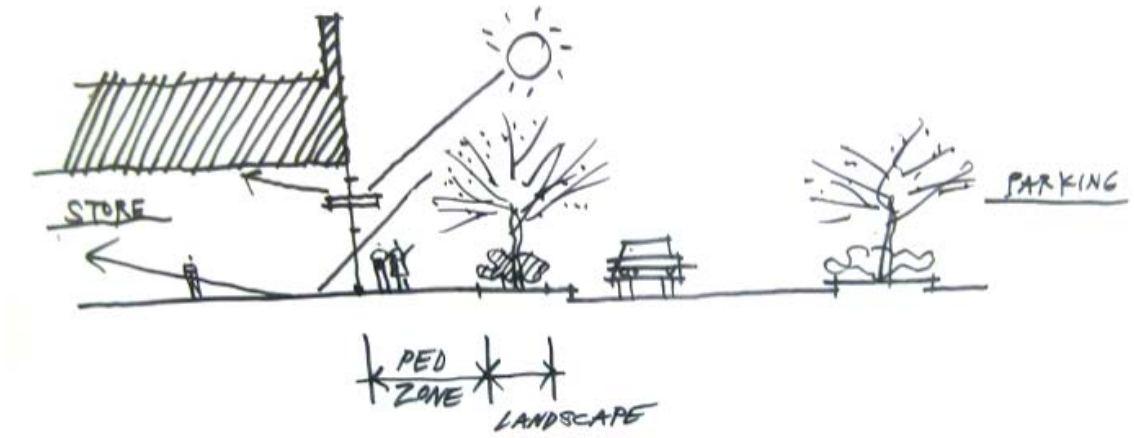
B.1.7 Integrating Indoors and Outdoors

A key concept discussed at the charette was how changes being proposed for daylighting might also better integrate the interior of the store with the outdoor environment. In addition to the details for window and entrance designs optimized for daylighting discussed above, the group

discussed a desire to make the windows and window displays more accessible to customers from both inside and outside the store by moving exterior and interior walkways closer to windows.

Exterior green elements such as trees or shrubs could also be used strategically to reduce glare from sunlight on the windows, and provide an attractive view from the inside.

Figure 44: Connecting Indoors and Outdoors



B.2 Strategies for the Two-Level Prototype

The two-level prototype discussed at the charette shares some of the same design elements as the one-level prototype:,

- Glazing near entrances
- Glazing for window displays
- Cruciform layout
- Multiple entrances

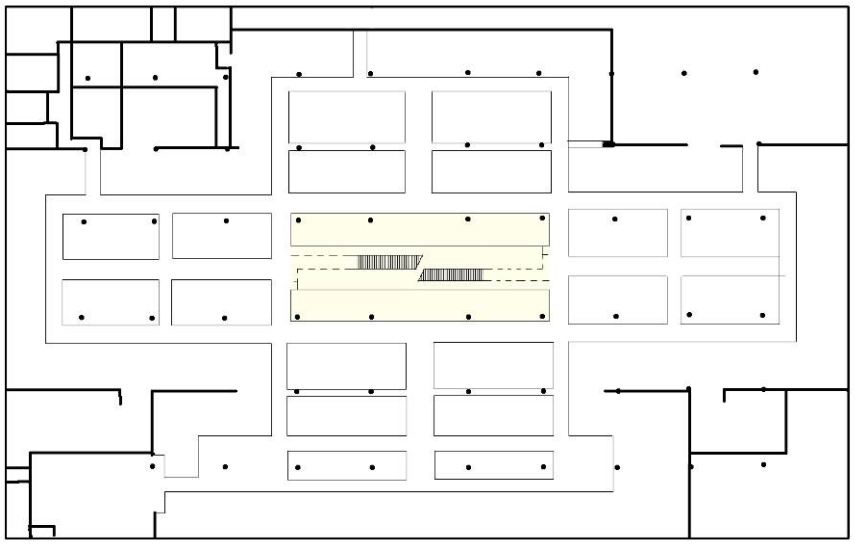
The key difference in the two-level prototype however, is that daylighting the lower level is far more challenging. While the upper level can benefit from skylights and raised window details similar to those discussed for the one-level prototype, these daylighting strategies are generally not available for the lower level. The group working on the two-level prototype store therefore concentrated on methods to bring daylight down to the lower floor of the store.

B.2.1 Daylighting the Central Escalator Atrium

The center of the two-level store consists of an atrium space with two escalators connecting the floors. The atrium, along with the escalators, connects the two floors visually and attracts attention to the second floor from the first floor. The intention of the design is to use the wall space next to the atrium for merchandise display.

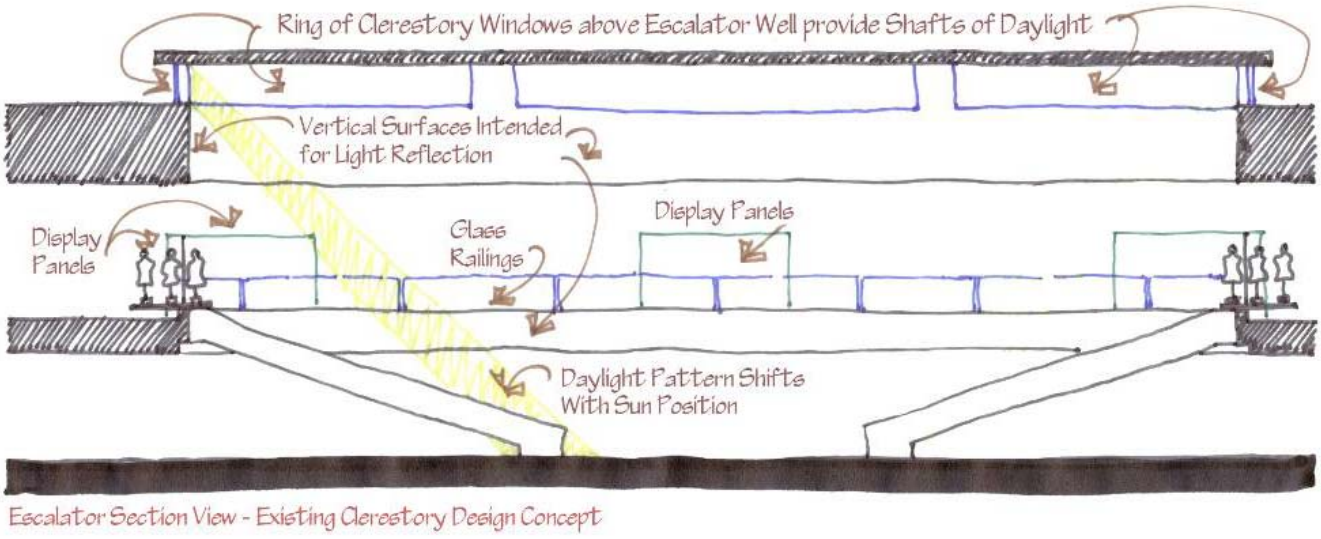
This central escalator shaft was discussed as a prime opportunity for bringing daylight into the store. Lisa Heschong pointed out that the prototype's escalator atrium space is evocative of the daylit central escalators atriums that are a common feature of the retail partner's stores in California. These daylit escalator atriums seem to have created, by themselves, a strong brand identity for the retail partner's stores in California. When hearing about this project, a large number of native Californians have spontaneously mentioned the retail partner's daylit atriums as a highly memorable aspect of their store design in the state. Clearly there was some early corporate intention to maintain consistency in story design with these daylit atriums to unify and reinforce the retail partner's shopping experience in California.

Figure 45: Typical Two-Level Prototype Plan View



The charette group discussions started with a proposal to include a row of clerestory windows above the roof of the atrium to bring a pool of daylight into the store – especially down to the first floor – while creating a visual 'wow' factor.

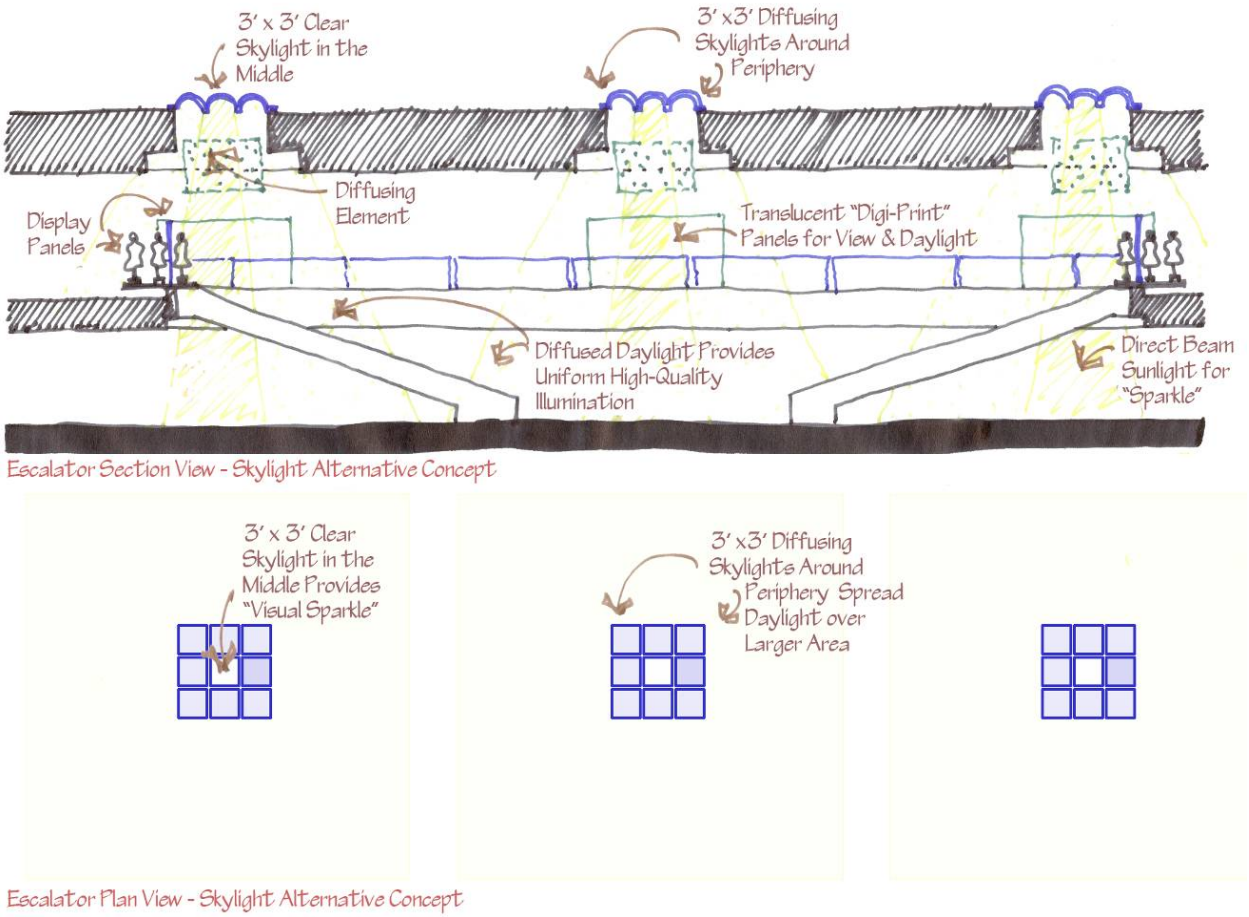
Figure 46: Escalator Well Daylighting With Clerestory Windows – Section



However, one of the challenges of clerestory windows, because they are vertical, is that their effectiveness varies with their orientation. Some directions will receive a great deal of high-angle sunlight, while others will receive mostly low angle sunlight, or very little at all. For a prototype design, where site constraints are unknown, orientation is typically not a controllable factor.

HMG recommended skylights as an alternative for the atrium. Three clusters of diffuse skylights could provide more illumination diffused more evenly throughout the atrium than the clerestory design. This is because skylights can provide 3 to 10 times as much daylight per square foot of opening than a vertical window. to include an element of sparkle, about 10 percent of the skylight area could be clear rather than diffusing. One solution could be to use a grid of nine 3’x3’ skylights, where the central skylight has clear glazing, and the surrounding eight skylights use diffused glazing. In general, unit skylights will be much more cost effective than the additional structural and glazing elements required for raised clerestories.

Figure 47: Escalator Well Daylighting With Skylights



While many of these details of the skylighting design options were discussed in the larger charette group, HMG also spent time with the architects participating in the charette afterwards to discuss these options in more detail. The dimensions and specifications of the skylights to provide the necessary illumination, as well as the spacing and location of the skylights would need to be worked out for the specific store designs for the retailer. Visual studies of the daylighting effect using visualization software would assist in this process, along with lumen calculations for sufficiency of the daylight under different climate conditions.

B.2.2 Window Daylighting Options

As discussed in Section 2.7 there are two main issues when working with windows – variability and directionality of daylight, and the resultant shadowing or silhouetting of displayed merchandise in front of windows.

The charette team working on the two-level prototype design, spent some time recapping the various alternatives to window daylighting and came up with the following rules-of-thumb:

- Where possible have merchandise displays arranged perpendicular, rather than parallel, to the window. This provides the best illumination and visibility for merchandise.
- Where possible include perpendicular surfaces, painted white or a very light color, adjacent to the window, to help diffuse the daylight deeper into the space. This can include ceiling, wall and/or floor surfaces.
- Wherever possible, try to provide "daylight from two sides" to help balance the light and avoid excessive contrast. This can include daylight from a window and skylight; from windows facing two orientations; from a bay window, either extending outward or re-entrant into the store; or direct plus secondary daylight bounced off of a reflecting surface.
- The use of translucent materials around windows, such as a 'digi-print', can help filter and diffuse daylight, while reducing glare and providing signage in one direction and filtered views in the other.
- Bounce direct sunlight off of one surface before it gets into the store.

B.2.3 Identify Most Attractive Daylight Options

Based on the goals and evolution of the prototype stores, those daylighting opportunities which seem most attractive and promising should be investigated further by the design team.

Interactions with other building systems, such as structure, roof drainage, HVAC, store layout, signage, etc., need to be identified and addressed. In general, daylighting is most successful when it is incorporated into the earliest phases of design, so that interactions with other systems can be integrated and optimized, rather than having one system dictate the choices for others.

Once particular solutions seem feasible, and design options have been narrowed down, specification choices and cost implications need to be investigated further. For example, window or skylight glazing specification including strength, UV blockage, thermal properties, visual properties need to be carefully investigated to optimize for performance and cost.

After investigating a number of options, the retail partner's design team will build experience and confidence in incorporating a growing repertoire of daylighting options into their store designs.

APPENDIX C:
Retail Daylighting Survey Findings

A brief summary of the observations from each survey location is included below.

C.1 Retail Store, Union Square, San Francisco

This six-story urban store occupies a full city block. The first floor has several display windows on each side, while the upper floors are fully glazed. Set back 1-3' behind the glazing is a layer of drywall with 8' square "windows" cut into it.

Because of the setback, daylight does not effectively reach the merchandise inside the store, and merchandise was often seen in silhouette against windows that produce a high level of contrast. Direct sunlight illuminated merchandise on the south side of the store, making it more visible from the street, but the highly reflective glass make window displays on other sides difficult to see during the day.

Illuminance levels in this store were the highest of all the stores visited, ranging from 50-80 foot-candles of ambient light with higher levels under accent lighting.

Figure 48: Daylight Conditions at the Union Square Retail Store

C.2 Bloomingdale's, San Francisco

This five-story urban location is fully glazed along the long southeast façade. This is used largely as an advertising opportunity to potential viewers from the parking garage across the street. Measured illuminance levels were lower than those in the previous retail partner location due to fewer fixtures and generally lower lamp wattages. Illuminance levels ranged from 35-50 foot-candles.

On the second through fifth floors, areas on the southeast side are lit by the extensive clear glazing. Semi-permanent walls are erected against the glazing to serve as backdrops for displays and branding. In most areas clothing racks were placed at 90 degrees to the window, so that the window wall and the racks formed the sides of a square area for each designer, with the aisle running along the fourth side. During the morning, sunlight penetrated 20'-30' into the space, coming in over the tops of the displays against the window wall.

Cash wraps are placed against the window wall. The staff whom researchers spoke with appreciated having access to daylight, and that they adjust their positions throughout the day as the sun moves to prevent the customers from having difficulty with reflections or glare while they are signing invoices.

On the south-east side there are clusters of four fitting rooms. The corridor leading to the fitting rooms runs along the window wall and is highly daylit, though the dressing rooms themselves have no daylighting. The staff said that the corridor becomes hot on summer days.

Figure 49: Daylight Conditions at Bloomingdale's San Francisco

C.3 Retail Store, Sunnyvale

This two-story suburban store has four skylights, each approximately 20′ square (each made up from two linear skylights, approximately 20′ by 8′ with a 4′ drywall soffit between). Skylights are located along each of the four main aisles radiating from the central atrium. The skylights were made of a Kalwall-like diffusing material. Diffusing luminaires were built into the soffit to provide uniform night-time illumination; these luminaires were switched off at the time of the survey visit. There was also a T8 fluorescent "cove" around the perimeter of the skylight that was turned on at the time of the visit.

The four skylights had merchandise places immediately adjacent to them, or in some cases, underneath an edge of the skylight, providing a high level of light on the display, and effective modeling of the merchandise.

The skylight material appeared from the inside to have yellowed and degraded. Visual inspection from the roof found that the fiberglass material had deteriorated. There was standing water found on the roof, but there was no evidence that the skylights were leaking.

Luminaires in the main retail space had been delamped (from 3 lamps to 2), but still provided a high ambient light level of approximately 50 foot-candles.

Figure 50: Daylight Conditions at the Retail Partner's Sunnyvale Location

C.4 Retail Store, Oakridge, San Jose

This two-story store had eight skylights of varying sizes, all located over merchandise areas instead of circulation aisles. A tinted film was applied to the inside of the skylights, and sales associates did not report any discomfort from sunlight. The UV film had bubbled in some places, but appeared to be in generally good condition. The skylights also showed no signs of leakage or previous repairs.

Skylights were approximately 20′ square, composed of acrylic linear skylights approximately 20′ by 4′, with 18″ soffits in between. Each soffit had either one or two linear fluorescent pendants suspended from it. Electric lighting was turned on during the visit despite adequate level of daylight.

This store also has a window at the end of the long axis on the second floor, though much of the light from the window is blocked by a display of children's clothing. The sides of the window are not blocked, and in these areas the clothes are appealingly lit by daylight. There were also several displays placed around the edge of the escalator well, which had clerestory windows around the edge. During the afternoon at the time of the visit, sunlight was coming through the west clerestories, and illuminating a display of tableware.

Figure 51: Daylight Conditions at the Oakridge, San Jose Retail Store

C.5 Retail Store, Newark

This two-story store has a 15' square tinted acrylic skylight located above the children's section, at the end of the long axis of the store. The children's section appeared conspicuously bright from the top of the escalator. The bright and colorful children's cloths appeared very attractive under the skylight, and double layered display walls (with a second row of merchandise above the first) are visible from a long way away.

Spot lights surrounding the skylight were turned off at the time of the visit. The illuminance under the skylight was 170 foot-candles at 9am. No photocell was visible from inside, so the spotlights are assumed to be controlled on a timer or from an exterior photocell.

The cash wrap was under the southwest edge of the skylight. The sales associate working under the skylight said she was never bothered by heat or glare from the skylight, but that she was bothered by heat from the 25 Watt spotlight over the cash wrap. The sales associated also reported that the skylight had been covered due to leakage problems, but that it had since been repaired and reopened.

Exterior windows visible from the outside open onto storage and staff areas. This appears to have been the design intent of the store.

Figure 52: Daylight Conditions at the Newark Retail Store

C.6 Retail Store, Pleasanton

This is the sister store to the Newark location, though this store is located in a more prosperous area, and has had more recent upgrades, including upgrading to white louvers on the light fixtures. Similar to the Newark store, there is a 15' square skylight, although in this store it is in the women's suits department.

Mannequins were placed slightly in front of the skylight, so they appeared in silhouette against the bright daylit area behind them, despite being lit by spotlights.

The cash wrap was located off to the side amongst the merchandise so it was not located underneath the skylight. Like the Newark store, spotlights in the skylight well were turned off at the time of the visit.

Ultraviolet film was installed on the inside of the atrium skylight in 2006, and the interior walls of the atrium were painted white, whereas the atrium walls at Newark were a slightly beige white. The cooler white paint at Pleasanton produced a cool light around the whole escalator area, which contrasted with the warmer white of the fluorescent lighting. This was an attractive contrast that made the atrium feel very naturally lit.

The skylight showed some evidence of past leakage, but it has since been repaired, and store staff says it is no longer leaking. There was no visible photocell in the skylight well, so the spotlights in the skylight well are either on a timer or controlled by an exterior photocell.

Figure 53: Daylight Conditions at the Pleasanton Store

C.7 Retail Store, Men's Clothing, Walnut Creek

This location has four small skylights (up to 10' square) over the men's suits department on the top floor, which do not admit a significant amount of light. On the second floor there was a

section with Ralph Lauren clothing which had a large window facing out over the street, looking through a deciduous tree. The window is surrounded by white shutters that softened the brightness of the window and created an attractive, beachfront feel. Merchandise was not placed against the window.

From the outside of the building four such windows are visible, but only one was in a display area. The other three windows were in office or storage areas.

Figure 54: Daylight Conditions at the Men's Store Walnut Creek

C.8 Hardware Store, Martinez

At this rural hardware store there were thirty Ciralight unit skylights on the roof. These skylights have a moveable mirror that tracks the sun and is intended to admit more daylight into the space during the early morning and late afternoon than a conventional skylight. During the visit, one skylight was covered with a tarpaulin, and two were pointing in the wrong direction. At 3:00 in the afternoon the two skylights that were malfunctioning did not appear to be admitting any less light than the functioning ones.

There was an average of 250-300fc on the sales floor, while the outside illuminance level was 6000fc. The merchandise appeared brightly lit and colorful, and the skylights were bright but not glary.

Figure 55: Tracking Skylights and Daylit Aisles at a Hardware Store, Martinez

C.9 Retail Store, Fairfield

This two-story suburban store has two sets of four diffusing barrel-vaulted skylights, each measuring approximately 16’ by 24’, located along the main north-south axis of the store.

The skylights are a double-layered acrylic, with a clear layer over a diffusing layer. The north skylight was located in the children’s and lingerie departments, positioned mostly over a cash wrap. The south skylight was located in linens, cookware and luggage departments. Sales associates at the cash wrap under the north skylight said that customers sometimes have difficulty signing the pads because of the reflections in the horizontal screen surface, but that the reflections are due to electric light as well as to daylight. They said that it gets hot under the skylight in the summer.

Each skylight was also surrounded by multiple electric lighting sources, including compact fluorescent and metal halide downlights, as well as fluorescent cove lighting. In total, 2700 Watts (7 W/sf) surround each skylight.

Figure 56: Daylight Conditions at a Retail Store in Fairfield

C.10 Retail Store, Roseville

This two-story suburban store has one long ridged skylight over the escalator well. This skylight has an applied film with alternating clear and diffuse strips, allowing direct sunlight as well as diffusing natural light throughout the space. A circular aisle surrounding the escalators allows some merchandise to be displayed close to the skylight. The merchandise in this area was attractively lit with a combination of direct and diffuse sunlight.

The store has high windows that extend from the first through the second stories, though on the second story the windows are blocked by drywall and not visible from inside the store. On the first floor, the windows extend about 30’ to either side of the entranceways, and there are several displays of clothing set next to the window. Generally, reflections in the glass prevent

these displays being visible from outside during daytime hours, but they are attractive from inside the store.

Figure 57: Daylight Conditions at a Retail Store, Roseville

C.11 Roseville Mall

The Galleria Mall at Roseville uses daylight to accentuate its colorful and playful architecture. Clear glass skylights are set into the roof between the checkered arches, and they brightly illuminate the sides of the arches, producing striking bands of bright and dark from most vantage points along the mall's main axis. Daylight is also used in the central dining area of the mall. Semi-circular bands of flat glass skylights are used to add light to an arcade that runs around the perimeter of the dining area, and the reflected sunlight (turned pink by the colored

wall of the arcade), makes the restaurant signs appear to glow from across the other side of the dining area.

Figure 58: Daylighting at the Roseville Mall

C.12 Scandinavian Designs, Rocklin

This new single-story suburban store has very high ceilings, up to around 40′ over the central aisle. The form of the building is similar to a church, with a high central nave and lower side aisles. The long axis of the nave runs north-south. Daylight is admitted through extensive glazing on the east and west sides, through windows with a head height of approximately 9′. Daylight is also admitted through high clerestories at either side of the nave, and through a full height (40′) window at the north end of the nave.

The approach to the parking lots passes by a display window on the south side of the building, which is fully glazed and has a raised pedestal running across half the width of the building, on which furniture is displayed. This display window is very eye-catching both from the approach road and from Highway 65 which runs just beyond the parking lot.

Figure 59: Daylighting at Scandinavian Designs, Rocklin

C.13 Raley's Bel Air, Sunrise Location

This grocery store is uniformly lit with rows of diffusing skylights set into splayed drywall reveals. The splayed reveals create a soft gradation of lit from the bright skylight to the dark ceiling, creating very comfortable visual conditions. The store is approximately ten years old and the lighting controls switch off one or two of the three lamps in each T8 light fixture.

Figure 60: Daylighting at Raley's Bel Air, Sunrise Location

C.14 Cameron Park Library

This branch library is in the rural community of Cameron Park near Sacramento. Like Scandinavian Designs, the building is shaped like a church with a high nave and lower aisles that run the length of the building. Diffusing skylights in the nave provide most of the daylight, and their brightness is tempered by colorful drapes that hang across the space. The drapes themselves appear very bright and colorful under the high light levels beneath the skylights.

Small side windows on the north side provide views and a moderate amount of light to reading areas immediately adjacent to the windows, though long overhangs exclude much of the daylight.

Figure 61: Daylighting at Cameron Park Library

C.15 Retail Store, Rancho Cucamonga

This two-story store was recently constructed in a "lifestyle" center, for example, an outdoor mall that resembles a main street. Architecturally, it closely resembles the Roseville store, except that the two-story windows are not blocked off with drywall, so are visible from inside the store.

Figure 62: Daylight Conditions at the Retail Store, Rancho Cucamonga

C.16 Retail Store, Home Furnishings, Costa Mesa

This three-story store is the largest and most recently built of the three retail partner locations at South Coast Plaza. Architecturally, the building is very different to any of the other retail partner stores surveyed, in that it has a single very large two-story window on the east side. It also has a central, skylit atrium, along with a small west-facing window on the west side, and a glazed entranceway on the second (ground-level) floor.

The large east-facing window is a highly visible feature of the store, both from inside and from the main pedestrian approach route (an elevated path that leads across the parking lot to another section of the mall). The window is visually striking, with large diagonal structural members that add depth and interest to the window. The window has clear glass and no exterior shading.

At the time of the visit there was a display of dinnerware, immediately in front of the window, and despite being viewed mainly in silhouette the merchandise was clearly visible from the interior of the store because the light surfaces on the floor and ceiling produced a lot of interreflected daylight. There were several vertical wooden display cases in the window, in which warm color temperature fluorescent lamps contrasted with the cool color of the incoming daylight. This color contrast appears striking in the photographs, and was also visible to the eye.

Several very long, diaphanous drapes in pale colors were hanging from the ceiling, approximately ten feet back from the window. These drapes helped to create a dramatic sense of height in the space, but did not significantly affect the incoming light.

The west-facing window is much smaller, only around 20′ wide and 12′ high, and significantly obstructed by large structural beams. It produced a pool of light close to the window which was effective in lighting a pair of beds placed immediately next to the window, but did not admit light further into the space.

Figure 63: Daylight Conditions at a Retail Store, Home Furnishings, Costa Mesa

C.17 Retail Store, Women's Clothing, Costa Mesa

This two-story store was built in the 1980s, and uses the same type of Kalwall-like skylight material as the Sunnyvale store. There are two skylights on the roof, one large west-facing skylight over children's clothes, and one small north-facing skylight over lingerie. The west-facing skylight has an unusual shape that maximizes the admission of afternoon and evening sunlight. The north-facing skylight was not admitting very much light at the time of the visit (early afternoon), but the larger west-facing skylight was giving enough light to create a glow that was clearly visible from the top of the escalator.

The daylight over the children's clothes created a very appealing soft glow that made the bright colors of the clothes stand out. Accent lighting on the clothing displays was still visible. The

aisle leading to children's clothes was paved with light colored tiles and was clear of merchandise, which meant that a reflection of the skylight was visible in the floor; this enhanced the glow of the skylit area from the top of the escalator.

The Kalwall-like material was even more degraded than at the Sunnyvale store. Much of the glass fiber on the outer surface was missing, leaving a smooth dark epoxy. The skylight provided a range of 60 to 80 foot-candles in the children's clothing department at 2:00pm. There was a single photocell on the roof that the facilities team said controlled both interior and exterior lighting. However, at the time of the survey, all the electric lighting in the children's clothing section was on.

Figure 64: Daylight Conditions at the Retail Store, Women's Clothing, Costa Mesa

C.18 Retail Store, Men's Clothing, Costa Mesa

The men's store is the smallest and oldest of the three stores at South Coast Plaza. The only daylit feature of the store apart from a small escalator skylight is a recently-constructed bridge that links across to the women's store. The bridge is fully glazed on the west side, and looks out across the plaza. It has two comfortable leather chairs, a series of clothing displays, and light reflective interior finishes. It is an architecturally interesting space that draws people in from both stores, and the experience of walking across the bridge is visually refreshing.

Figure 65: Daylight Conditions at the Retail Store, Men's Clothing, Costa Mesa

C.19 High-End Retail Store, Costa Mesa

There was no daylighting at this store. The store had been recently refurbished, and it appeared that a skylight over the escalator had been covered over. The store's original exterior had been retained, but completely covered over with a new structural steel and diffusing glass façade. Because the original walls of the building were behind the new façade, no daylight was admitted into the store.

C.20 Acralight Factory and Showroom

Acralight arranged a tour of their factory to discuss the various materials, manufacturing technologies, design approaches and technical features of their skylights.

C.21 Retail Store, Women's Clothing, Manhattan Beach

This two-story store was the third in the survey that had skylights made of a Kalwall-like (translucent) material. There was a long pyramidal skylight over the escalator and an angled skylight over the entranceway, which spilled some light into the lingerie section on the second floor. Because the lingerie section was set back from the skylight,, which reduced the amount of daylight in the lingerie section at the time of our visit.

The Kalwall in these skylights was terribly degraded, and from the inside of the store the skylights appeared a patchy dark yellow or orange color. In some cases the cells of the skylight were almost opaque. The facilities manager was actually not aware that there were skylights in the store.

In this store, ambient lighting is provided by suspended uplights, each of which originally had one high pressure sodium and one metal halide lamp. Since neither of these sources can be dimmed in a cost-effective way, and both have extended ignition times which make them not suitable for saving energy by daylight harvesting.

Figure 66: Daylight Conditions at the Manhattan Beach Women's Store

C.22 Retail Store, Men's Clothing, Manhattan Beach

This store has a glass skylight over dinnerware displays in the center of the second floor, next to (but not directly over) the escalator. The skylight is an octagonal pyramid approximately 18 feet in diameter and ten feet high. The structural elements of the skylight create a kind of dappled shade over the displays in some areas, and patches of bright sunlight in others. he area underneath the skylight was conspicuously bright and drew attention from everywhere on the second floor. he sales assistant at the cash wrap underneath the skylight said that she would rather have the skylight than not have it, and that she has noticed that customers stand in different positions around the cash wrap depending on the position of the sun.

It was noticeably warmer underneath the skylight at the time of the visit (11:00) under direct sunlight. he glass did not appear to have had a film applied to it.

Figure 67: Daylight Conditions at the Manhattan Beach Men's Store

C.23 Manhattan Beach Mall

The mall at Manhattan Beach is unusual in several ways. It doesn't include grand or baroque features. It has a great deal of vegetation and public seating, and it makes use of suspended elements to filter and redirect the daylight admitted from clear glass skylights. White-painted wooden lattices are suspended beneath each skylight, and each side of the lattice is angled slightly downward to allow daylight to reflect on to the surrounding ceiling, producing a graded luminance.

At the time of the visit the sky was clear, and beneath each skylight there was a patch of sun broken up into soft-edged squares by the lattice above. The ceiling of the mall concourse is low in comparison to other malls, but the lightness created by the lattices makes the mall appear open and spacious. The lattices themselves are the most visible architectural feature of the space, whereas in many malls the most visible features are arches, columns, or walkways.

Figure 68: Daylighting at a Manhattan Beach Mall

C.24 Prada, Rodeo Drive

The Prada store, recommended by Acralight, as being an interesting example of a daylit store. The second floor ceiling is composed of closely-spaced galvanized beams, approximately 15" wide and 15" apart. A continuous sheet of green glass is laid on top of the beams. Unshielded T8 lamps, are attached to the top corner on one side of each beam, and spotlights are suspended at irregular intervals.

The beams run east-west, and the close spacing minimizes direct sun penetration, although during the height of summer direct sun would shine down between the beams. At the time of the visit, the sky was overcast, and the effect inside the store was very similar to an overcast, leaden sky.

The store itself was completely open to the street. It had no doors or windows on the first floor level, and the sidewalk transitioned smoothly into the floor of the retail space, making the store feel like public space. Many of the stores on Rodeo Drive, where street frontage is expensive, used spatial and lighting techniques to draw the attention of passersby. These techniques included fully glazed store fronts, illuminated panels, backlit displays inside the stores, and lines of light that draw the eye into the space.

Figure 69: Daylighting and Electric Lighting at Prada and Other Stores on Rodeo Drive

C.25 Getty Museum

The Getty Museum is a private museum open to the public for a low fee. It is situated on top of a steep hill overlooking Santa Monica and Los Angeles, and is only accessible by tram from an

entrance plaza in the valley below. The long views, absence of vehicle noise, open architecture, and frequent water features make the Getty Museum a very relaxing and calm environment.

Outside, under sunlight, the pale buildings and paved areas have a high brightness, while the interior of the galleries are much darker, at around 15 fc. The architecture creates very gradual transitions from bright to dark, so that the interior never appears gloomy and the outside never appears excessively bright. These transitions are accomplished by the massing of the buildings, and by the use of overhangs, window reveals, and roller blinds. Mostly, the interiors of the buildings feel visually connected to the outside.

The sculptures are illuminated by a combination of highly controlled daylight (through moveable louvers) and electric spotlights. Even at noon on a clear day, the electric lighting was still switched on. The two types of light produced a combination of shadows—hard-edged blue shadows from the electric lights and soft-edged warm white shadows from the daylight. In addition to the use of daylight to model the shape of the sculptures, many of the exterior finishes of the building are highly textured or irregular, and direct sunlight reveals their shape and texture at specific times of day.

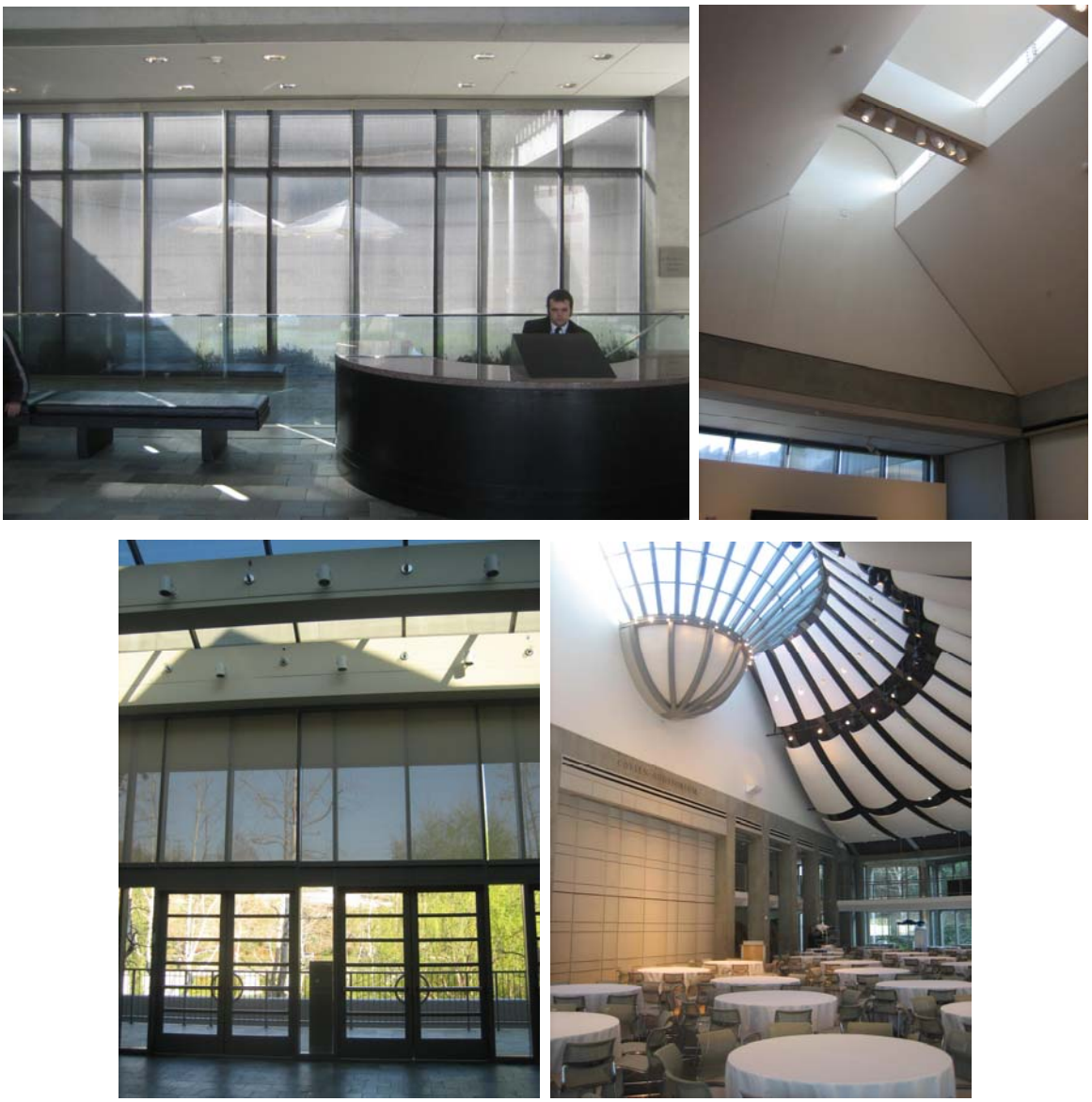
Figure 70: Daylighting at the Getty Museum

C.26 Skirball Cultural Center

The Skirball Cultural Center combines a permanent museum space, temporary exhibition spaces, conference rooms, and performance spaces. It is located close to the Getty Museum, on the side of a wooded valley with views over Los Angeles and the ocean. The Skirball is a Jewish institution with an explicit goal of tracing "the experiences and accomplishments of the Jewish people"; and the shape of the building reflects culturally significant architectural forms such as gardens, religious buildings and tents.

In contrast to the Getty Museum, the transitions from light exteriors to dark interiors are not gradual, and the interiors of the buildings feel shaded. Black roller blinds are used (in contrast to the white blinds at the Getty), interior finishes are not as pale, and the daylight levels in the toplit exhibition spaces are less than one third of those at the Getty. Again, in contrast to the Getty Museum, the interiors are not strongly visually connected to the outside, because views from inside to outside are mostly small or obscured by blinds. The artifacts on display illuminated by electric light, which comes from narrow beam spotlights recessed into beams beneath the skylights.

Figure 71: Daylighting at Skirball Cultural Center



APPENDIX D:
Intervention Study Design Details

D.1 Design Options for Skylight Re-Opening

The fundamental challenge with the existing skylight in the store was its size (23′ x 23′) and its thermal properties (likely single glazed) that led to excessive heat gains in the space, contributing to the decision to cover-up the skylights in the store. Any attempts to re-open the skylight therefore needed to account for the following comfort factors:

- Conductive heat gains from the skylight during summer and losses during winter and night-time
- Solar heat gain from the skylight
- Amount of useful daylight from the skylight, and
- The relative illuminance levels between the daylit area and the surrounding area lit with electric lighting

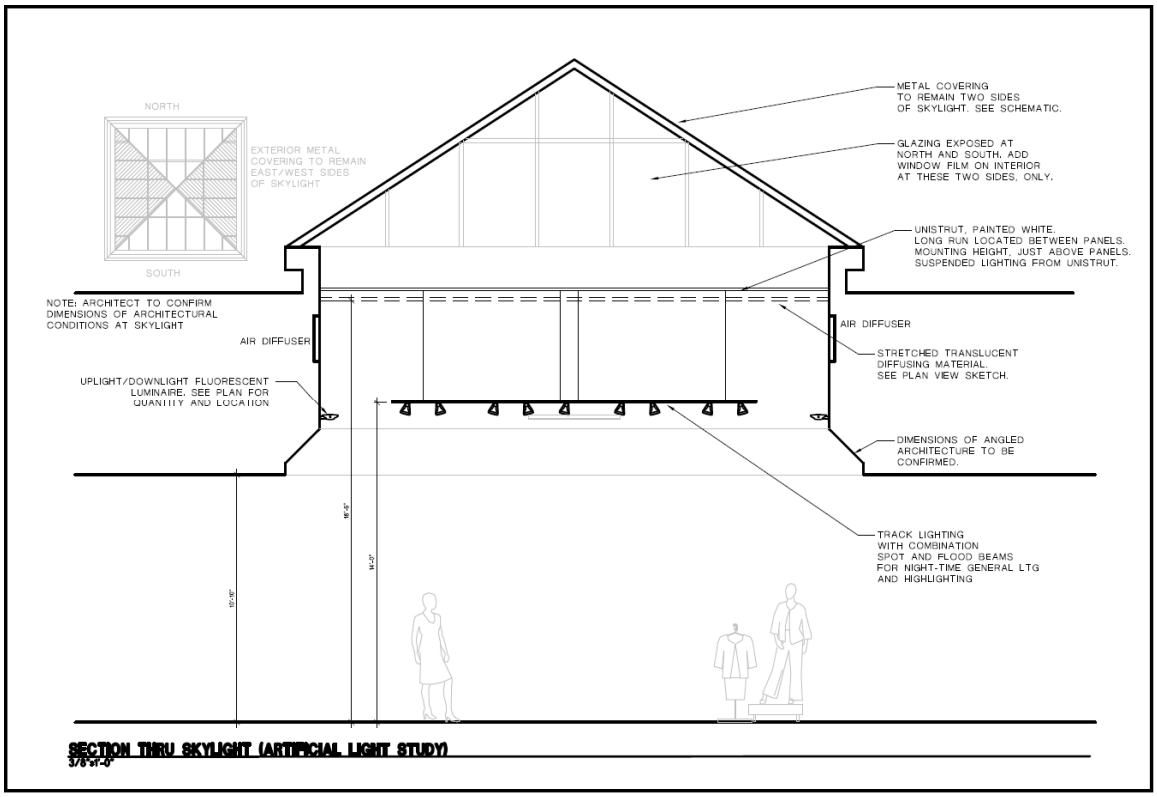
In addition, the proposed intervention strategy needed to also address the following design and intervention study objectives:

- Provide high-quality daylit visual environment, diffusing direct sunlight over a large area to allow a significant reduction in electric lighting energy use. This was the primary objective for the intervention study.
- Reduce solar gains from the skylight, avoid causing thermal discomfort or overloading the HVAC system in the store.
- Minimize costs and sales impact for the skylight restoration – the retail partner had a limited construction budget to conduct the daylighting intervention study and therefore it was important the proposed solution be the 'least-cost' retrofit that achieved the other intended design criteria.

HMG worked with retail partner's design staff on several options to open the skylight over the study area. While the retail partner team developed the design options and costs, HMG conducted energy and daylight illumination impacts assessment of the various options.

At the end of the design process, after discussing several skylight design options with the retail partner, and energy simulation analysis, the team arrived at a consensus design as shown below in Figure 72.

Figure 72: Final Skylight Intervention Physical Design Solution



Key concepts incorporated in this design included:

- Remove the exterior metal covering from north/south sides of skylight only. Thus, the east/west sides of the skylight would continue to have the insulated metal covers.
    - This reduced the amount of glazing area by 50 percent and had two advantages –
        - Reduced overheating the space, due to lower solar gains
        - Reduced over-illumination of the space due to smaller skylight aperture

- Install solar and UV reducing film on the restored glazing surfaces of the skylights. Based on review of available window films, the following two or their functional equivalent were proposed for the study:
    - Sunrise Bronze (V33 BR SR CDF) from Vista Window Film - 36 percent VLT, 0.32 SHGC, 0.98 U-value, 68 percent TSER (Total Solar Energy Rejected)
    - Prestige Series PR40 from 3M films - 39 percent VLT, 0.47 SC or ~0.36 SHGC, 0.99 U-value, 66 percent TSER at 60 percent incidence

- Suspend stretched translucent panels in skylight throat to help shield view of existing skylight construction.

    - This was primarily for aesthetic reasons so that unexposed sides of skylight did not have to be finished from the interior, thus minimizing costs.
    - It also had the advantage of increasing downward reflection of electric lighting at night, helping to diffuse any direct sunlight, and helping to stratify any excessive heat gain.

- Separately control electric lighting in and around the skylight well, with daylight sensors so that these fixtures are turned off for a majority of the daylit hours to achieve energy savings.

Once this design was approved, the retail partner proceeded with the construction activities, and HMG started work on developing the surveys to be administered to the customers and sales associates.

APPENDIX E:
Intervention Study Surveys

E.1 Survey Intent

The daylight intervention study was designed to obtain feedback from a real-world working retail environment on the impacts of daylighting. To gather this feedback, HMG and the retail partner decided that HMG staff would conduct brief surveys of customers as well as sales associates working in the areas affected by the daylighting intervention (study area) as well as other areas of the store (control area) for comparison purposes.

The goal of the in-store surveys was to provide qualitative data that could be compared to the quantitative sales data analysis provided by the retail partner. The survey sought to answer the question of how the re-opened skylight impacted shopper and sales associate perceptions of the store. Separate survey instruments were developed for the customers and the sales associates to best identify the unique impacts of the intervention on each group.

E.2 Survey Instrument

Survey questions used a seven-point Likert scale for responses. The questions asked shoppers and sales associates to evaluate various qualitative aspects of how they experienced the space, without specifically drawing attention to the skylight, to avoid response bias. Questions included topics such as the attractiveness of the merchandise and the shopping environment, ease of wayfinding in the store, and helpfulness of sales associates. To best evaluate how attitudes changed after the skylight was re-opened, all survey questions were the same for both pre- and post-retrofit surveys.

Below is a brief summary of the questions asked of the customers and sales associates.

E.3 Customer Survey

The survey of customers gathered data on the following:

- Survey location (department where the customer was surveyed)
- Date and time of the survey
- Name of the surveyor conducting the survey
- Age, gender of the customer
- Number of companions with the customer
- Frequency of the customer's visit to the particular department as well as the store

- Customer's rating of the attractiveness of the clothing, merchandise displays, the department and the store
- How easily can the customer read or gauge merchandise displays, signage, quality and color of merchandise and merchandise labels
- Ease of wayfinding in the department as well as the store
- Customer's perception of the helpfulness of the sales associates

E.4 Sales Associate Survey

The survey of customers gathered data on the following:

- Survey location (department where the customer was surveyed)
- Date and time of the survey
- Name of the surveyor conducting the survey
- Normal work hours, work location and tenure of the sales associate
- Sales associate perception of change in the amount of time customers have spent in the department and in talking with sales associates or trying on clothes within the past week compared to previous month
- Sales associate perception of change in the number of transactions in the department, rate of product returns and change in frequency of visit by regular as well as new customers within the past week compared to previous month
- Feedback from customers on the appearance of the department, store, merchandise displays or attractiveness of clothing
- Sales associate comfort in their place of work in relation to illumination levels, thermal environment and the acoustic environment

E.5 Survey Methodology

In order to understand the impacts of the intervention, HMG conducted surveys of both shoppers and sales associates, before and after the skylight was re-opened.

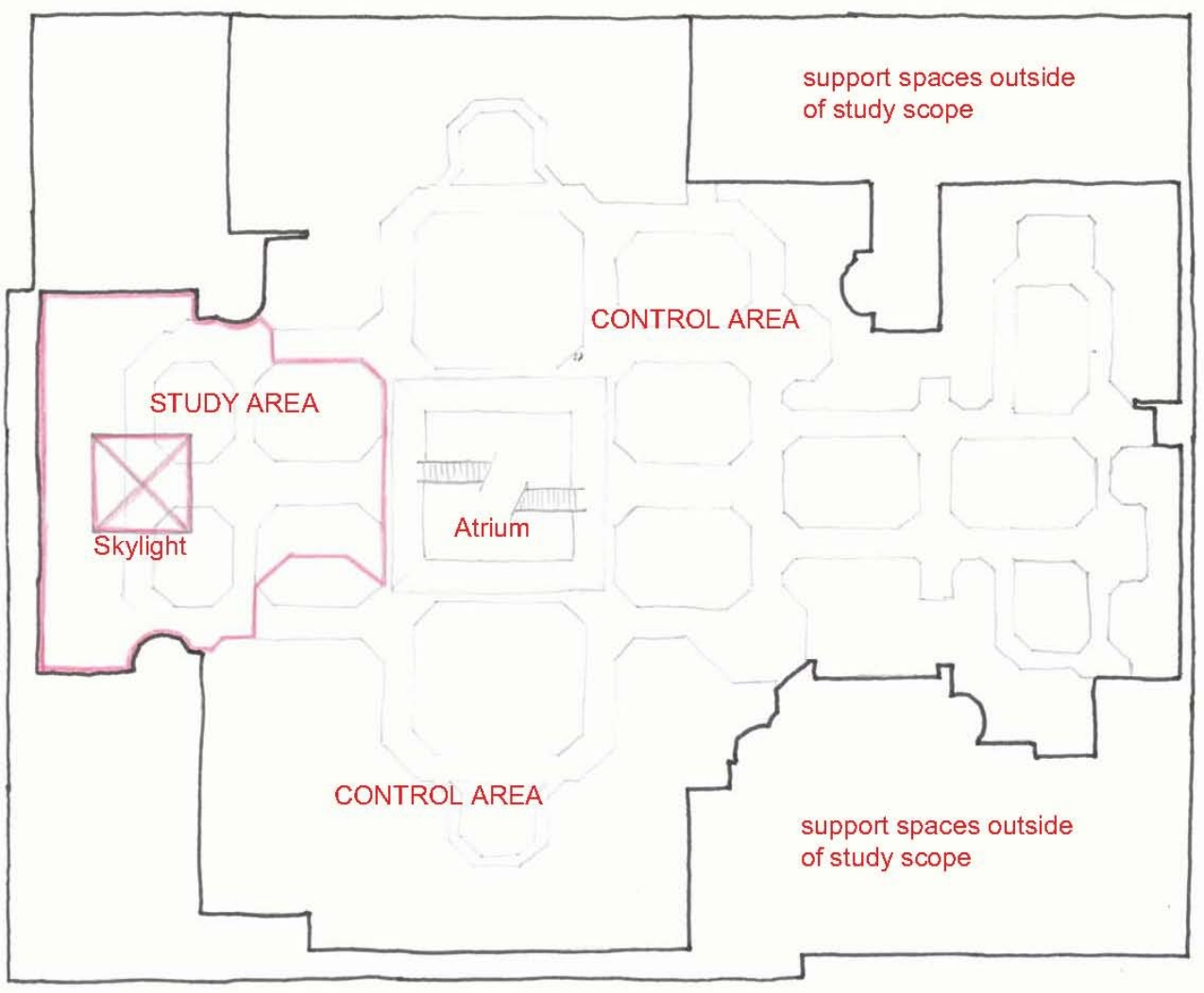
HMG coordinated with the retail partner to establish the dates for the on-site surveys. Each round of survey took place over a period of two days, with a preference for Fridays and Saturdays when shopping traffic was highest. Survey dates were coordinated with retail partner management to ensure consistent merchandising and sale conditions, as well as with the store manager to avoid interference with regular store operations. Sales associates were also notified of the presence of the surveyors.

Two surveyors from HMG were in the store from store opening time until approximately dusk, to collect survey responses at those times of the day most impacted by the presence of daylight.

HMG trained surveyors in-house prior to survey dates, to establish consistent practices between different surveyors, and to make sure that surveyors were familiar with the survey instrument and the questions. As much as possible, the same personnel were used for all survey dates to ensure consistency across the survey periods.

During the survey periods, the surveyors would circulate throughout the study and control areas, spending approximately equal time in each area. As noted in the Chapter 6, the study area consisted of the approximately 8000 square foot area immediately surrounding the re-opened skylight, while the control area was made up of the remainder of the third floor sales area, as shown in Figure 73, below. Surveyors approached customers at random and interviewed any that were willing to participate. The goal was to get approximately 100 customer responses for each survey period, with an approximately equal number of responses for the study area and the control area. Surveyors also interviewed sales associates in their downtime when they were not helping customers.

Figure 73: Location of "Study" and "Control" Areas in the Store



Survey responses were collected by hand by the surveyors, and later entered into Microsoft Excel for analysis. All data entry was performed by the same person to ensure consistency, with spot checks between the original surveys and the entered data to check for entry errors. Data was filtered during analysis to check for surveyor bias and, when necessary, adjustments were made to correct for any surveyor bias in the narrative.

E.5 Survey Implementation

In-store surveys were conducted before the skylight retrofit, and at three intervals after the skylight was re-opened. Pre-retrofit surveys were conducted on August 28- 29, 2009 and September 4-5, 2009. Initial post-retrofit surveys were taken on October 23, 2009, with an additional round of surveys taken on October 29 -30, 2009. Following some adjustments made in the store, a final round of surveys was conducted on April 15, 2010.

Number of survey responses collected during the various site visits is as follows:

Pre-Intervention Surveys

- August 28 and 29, 2009:
    - 97 customer surveys (66 in study area, 31 in control area)
    - 25 sales associate surveys (11 in study area, 14 in control area)
- September 4 and 5, 2009:
    - 111 customer surveys (61 in study area, 50 in control area)
    - 8 sales associate surveys (4 in study area, 4 in control area)

Pre-Intervention Totals:

- 208 customer surveys
    - 127 in study area
    - 81 in control area
- 33 sales associate surveys
    - 15 in study area
    - 18 in control area

Post-Intervention Surveys:

- October 23, 2009:
    - 39 customer surveys (28 in study area, 11 in control area)
    - 8 sales associate surveys (7 in study area, 1 in control area)
- October 29 and 30, 2009:
    - 203 customer surveys (72 in study area, 131 in control area)
    - 23 sales associate surveys (4 in study area, 19 in control area)

- April 15, 2010:
    - 78 customer surveys (32 in study area, 46 in control area)
    - 8 sales associate surveys (4 in study area, 4 in control area)

Post-Intervention Totals:

- 320 customer surveys
    - 132 in study area
    - 188 in control area
- 39 sales associate surveys
    - 15 in study area
    - 24 in control area

E.6 Customer and Sales Associate Survey Results

HMG crafted two separate surveys, one for customers and one for sales associates. Both surveys were written with questions that did not specifically mention the skylight, but rather asked survey respondents about the visual comfort, visibility, and attractiveness of their surroundings. Each survey was a series of multiple-choice questions with answers to be given on a 7-point scale. Answers were analyzed based on the numerical point-value assigned by the respondents to each question. Below is a report on the process and the results of survey analysis.

HMG conducted two sets of surveys. The pre-retrofit surveys were conducted in August/September 2009 while the post-retrofit surveys were conducted in October 2009 and April 2010. Analysis of survey data combined responses from various dates into composite pre- and post-intervention data sets to control for variations or anomalies that may have skewed the results from any single survey date. Combining the data from various dates also accounts for the constantly changing merchandising conditions in the retail environment.

The total number of survey responses for customers and sales associates were as follows:

Table 2: Number of Customer and Sales Associate Survey Responses

		Customer	Sales Associate
Pre-Skylight	**Total**	**208**	**33**
	Study Area	127	15
	Control area	81	18
Post-Skylight	**Total**	**320**	**39**
	Study area	132	15
	Control area	188	24

Survey analysis was conducted using a statistical analysis tool (R) to evaluate the change in response between the pre-skylight and post-skylight conditions, adjusting for surveyor bias, age of survey respondents and location of survey. A ratio of pre-skylight to post-skylight responses was generated separately for the study area and the control area for each question using the equations below:

$$\text{Study Area Ratio} = (\text{avg value post survey})_{\text{study area}} - (\text{avg value pre survey})_{\text{study area}}$$

$$\text{Control Area Ratio} = (\text{avg value post survey})_{\text{control area}} - (\text{avg value pre survey})_{\text{control area}}$$

The difference between the study and control areas was then used to analyze the relative change in customer and sales associate feedback for the study area compared to the control areas using the following equation:

$$\text{Delta Ratio} = \text{Study Area Ratio}/\text{Control Area Ratio}$$

Below are two tables of survey responses analyzed for trends in customer and sales associate responses. Where the trend was positive (positive delta ratio), a yellow colored cell with an upward arrow is used. When the positive trend is substantial (a jump in responses by close to one point on a 1-7 scale) it is identified with a green colored cell with a double arrow pointing upward.

Alternatively, when the trend is negative (negative delta ratio), these cells are highlighted by tan colored cell with a downward pointing arrow. When the negative trend is substantial, it is identified with an orange colored cell with a double downward pointing arrow (substantial

negative trends were not found for any of the survey questions, and are therefore not shown in any of the tables below).

E.6.1 Customer Survey Results

Table 3: Customer Survey Analysis Results

Survey Question Text	Delta Ratio (post-pre)	Overall Trend of Responses	Interpretation of Trend
Time since Last Time in Dept	0.08	–	More repeat customers in study area compared to control area
Time since Last Time in Store	0.26	↑	
Attractiveness of Clothes for Sale	0.17	↑	Customers are finding it easier to evaluate merchandise and find the study area to be more attractive post-retrofit. Glare from electric lighting can make it hard to read displays or evaluate quality.
Attractiveness of Merchandise Display	0.15	↑	
Attractiveness of Dept	0.11	↑	
Attractiveness of Store	0.12	↑	
Easy to Read Merchandise Display	(0.02)	–	
Easy to Read Overhead Signage	0.27	↑	
Easy to Gauge Merchandise Quality	(0.02)	–	
Easy to Gauge Merchandise Color	0.10	↑	
Easy to Read Merchandise Tags/Labels	(0.23)	↓	Customers are finding it hard to read merchandise tags or find way around the store and the study area. However, this seems to be pervasive in the store and not to the study area in particular.
Ease of Wayfinding in this Dept	(0.11)	↓	
Ease of Wayfinding in this Store	(0.31)	↓	
Helpfulness of Sales Associates in this Area	0.03	–	Customers are generally happy with the quality of service from the sales associates
Helpfulness of Sales Associates in this Dept	0.07	–	
Helpfulness of Sales Associates in this Store	0.06	–	

As seen in Table 3 , the customers have a generally positive feedback to the daylighting retrofit. Overall customers rate the attractiveness of the department and the clothes slightly higher than in the pre-retrofit case. Customers seem to find wayfinding in the store to be more difficult.

Because of the structure of the survey questions, positive trends do not always indicate positive responses to the skylight. For example, for the first two questions, indicating the amount of time since the customer was last in the department or the store; positive trends indicate less frequent visits. While positive trends on these two questions indicate that shoppers are visiting the store slightly less often than those surveyed prior to the intervention, it is notable that the positive trend in the "time since last in the department" question is less than the trend for the store as a whole. In other words, even though the average frequency of overall store visits has decreased, frequency of visits to the study area department has not decreased as much. Survey responses indicate positive trends in "attractiveness" of the store and merchandise as a result of the re-opened skylight, but trends were mixed for performance of visual tasks. Responses indicate that the daylight improves the ability to assess merchandise color and to read overhead signage, but had no effect on the respondents' ability to read merchandise display information or to gauge merchandise quality. Respondents' ability to read merchandise tags and labels declined in the post-intervention scenario, although this seems to be happening at the store-wide level and not limited to the study area.

Customers' increased perception of attractiveness is an indication that the skylight has improved the visual environment in the store, but the problems with visual tasks and wayfinding remain a point of concern. It is also possible that sources of glare caused by electric lighting could be responsible for visual task problems, but a cause-effect cannot be determined based on the data. Assessing changes in customer experience in the post-intervention condition was further complicated by the fact that initial survey responses in the pre-intervention condition were already positive, leaving little room for improvement.

E.6.2 Sales Associate Survey Results

Table 4: Sales Associate Survey Analysis Results

Survey Question	Delta Ratio (post-pre)	Overall Trend of Responses	Interpretation of Trend
Time Shoppers Spent In This Area of the Store	0.2	↑	Customers are spending more time in the study area and trying on more clothing indicating a positive visual impact of the daylighting
Time Shoppers Spent Talking with Associates	0.3	↑	
Time Shoppers Spent Trying on Clothes	0.6	↑	
Change in Number of Transactions in Dept	0.9	↑	Number of transactions have increased and product returns have reduced
Change in Number of Product Returns	(0.3)	↓	
Change in Number of Return Shoppers	1.1	⇑	The study area is getting more number of new and returning customers
Change in Number of New Shoppers	1.5	⇑	
Dept is Visually Attractive to Associates	0.5	↑	Sales associates are happy with the overall lighting conditions and think that ht daylighting adds to the merchandise visual appeal
Lighting Conditions are Comfortable	0.1	↑	
Lighting in Dept makes Merchandise Appealing	0.6	↑	
Parts of Dept are too Dark	(0.2)	↓	Electric lighting being on creates bright spots and glare. Overall light levels are balanced across the study area.
Parts of Dept are too Bright	1.9	⇑	
Lighting in Dept is Uneven	(0.3)	↓	
Lighting in Dept Produces Glare	1.3	⇑	
Temperature in Dept is Comfortable	(0.5)	↓	The skylight addition has not increased cooling loads. Complaints about being too cold indicate AC operation could be optimized or reduced
Temperature in Dept is Too Hot	(0.2)	↓	
Temperature in Dept is Too Cold	0.9	↑	
Distracted by Noise in this Dept	(0.2)	↓	There is no perceptible

Distracted by People Talking	(0.6)	↓	difference in the acoustic conditions of the study area due to opening of the skylight
Distracted by Music in the Store	0.1	↑	
Distracted by Noise from A/C	(0.4)	↓	
Distracted by Other Parts of Store	(0.1)	↓	
Distracted by other Noise Sources	(0.4)	↓	

Although there were fewer sales associate surveys, the changes in their responses in the post-intervention surveys tend to have a higher magnitude than the customer surveys. In addition to the clear trends, sales associate survey responses may carry more weight because they are spending the most amount of time in the department, and are more familiar with the conditions in the store and study area.

According to sales associate survey responses, shoppers were spending more time in the department, talking to sales associates, and trying on clothes, as indicated above in Table 4. Responses also indicated in increase in sales and a decline in returns in the post-intervention surveys. Perhaps most significant was the substantial increases in return and new shoppers in the area, compared to the pre-intervention condition (indicated in green, above, in Table 4).

Sales associates also indicated that the re-opened skylight improved the overall visual environment in the area, indicating positive trends in both overall attractiveness of the department and the appearance of the merchandise. However, responses to questions regarding lighting conditions were more varied. There was a slightly positive trend in overall lighting comfort and a slight decrease in the perception that parts of the department were too dark, but there was a significant increase in responses indicating that parts of the department were too bright (an increase of 1.9 as indicated above, in Table 4). As explained below the complaints about area being too bright are related to electric lights being on rather than daylighting being too powerful.

Responses regarding temperature were similarly varied. While there was a negative trend in overall temperature comfort, there was also a decrease in responses that the temperature was too hot. The introduction of daylight in the space did not increase the perceived temperature which is a significant achievement of the skylight retrofit design. In contrast, there was also a positive trend in responses that the temperature in the department was too cold. Whether this is directly attributable to the intervention study is unknown, but responses to this question had been consistently high throughout the store and in the pre-intervention survey. Overall, sales associate survey responses indicate that the re-opened skylight did not have a significant impact on the temperature or thermal comfort in the department.

Sales associate responses also indicated negative trends in noise distractions of all kinds, with the single exception of the music in the store (indicated in the last six lines of Table 4, above).

These responses suggest that the skylight is not having a negative impact on the acoustic environment in the store.

Overall, the sales associate surveys provide a very clear trend towards a more attractive study area where the customers are spending more time, trying on more clothes and an area that the sales associates like as well. Sales associates made numerous negative comments to our surveyors about the glare and visual discomfort from the electric light sources that are still on within and around the skylight well. These light fixtures being on creates a very bright pool of lighting around and underneath the skylight, and makes the rest of study area appear darker in comparison. The skylight, on the other hand, was considered a wonderful addition to the space, and received only positive comments.